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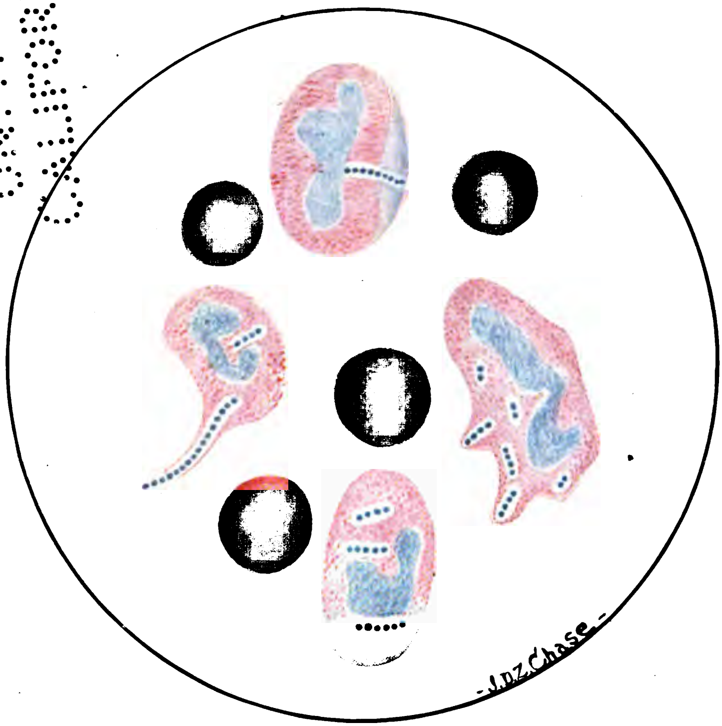
PLATE I



White Cells of the Blood, Leukocytes, acting as Phagocytes or Devouring Cells; Streptococci in Chains being Consumed.

ELEMENTARY

BACTERIOLOGY

AND

PROTOZOÖLOGY

FOR THE USE OF NURSES

BY

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SECOND EDITION, REVISED AND ENLARGED

ILLUSTRATED WITH 68 ENGRAVINGS AND
FIVE COLORED PLATES

LEA & FEBIGER
PHILADELPHIA AND NEW YORK
1916

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TO

MY WIFE

PREFACE TO THE SECOND EDITION.

In preparing the second edition of this book the same principles have been followed as directed its previous form. It has been found advisable to add some more details concerning general disinfection, the transmission of infection, especially in regard to those diseases spread by insects, and the peculiar phenomena of hypersusceptibility, a subject which becomes wider in its significance as we learn more about it. In regard to the special bacteria and diseases, only such material has been added as was needed to bring the book up to our present information.

H. F.

PHILADELPHIA, 1916.

PREFACE TO THE FIRST EDITION.

THE present work has been prepared to give the nurse and the beginner an idea as to the nature of microörganisms and their relation to the world's economy, especially in disease. For this reason much technical material has been omitted, especially in the subject of biological differentiation. Emphasis has been laid upon how bacteria pass from individual to individual, how they enter the body and act when once within, and their manner of exit. Such general information concerning the character of the disease process has been included as seemed necessary to clarify the nature of the microbe action. Indeed, the subject matter in many places is but elementary bacteriological pathology. During the preparation of the work the author has had in mind a question he has been asked repeatedly: How do bacteria produce disease? That this question is answered as simply and as well as our knowledge of today permits is the author's sincerest hope.

H. F.

CONTENTS.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

BACTERIOLOGY AND PROTOZOÖLOGY.

CHAPTER I.

INTRODUCTION—HISTORY—THE PLACE OF MICROÖRGANISMS IN NATURE.

INTRODUCTION.

THE study of disease has brought to light many facts which demonstrate the effect of the association of different forms of life. Chief among these is the fact that minute beings live upon greater ones, either harmlessly or to the detriment of the latter. The study of these small creatures is called microbiology, this being the portion of general biology in which the use of magnification is necessary. Bacteria are classified as plants and their study is called bacteriology. The smallest animals, protozoa, are considered in the subject of protozoölogy. To explain the causation of infectious diseases the physician has been obliged to study both of these subjects, that is, the large field of microbiology. The lowest forms of life are unicellular bodies capable of leading an independent existence, in contrast to the single units of the cell groups which go to make up the compound organism, a higher animal

or a plant. Some of these single-celled bodies have characteristics placing them without question among the plants, while others with equal definiteness belong to the animals. The line between is by no means sharp, and much difference of opinion exists among investigators as to the borderline forms.

HISTORY.

The existence of more or less independent forms of life invisible to the naked eye was first proven about two and one-half centuries ago by Van Leeuwenhoek and Kircher, who actually saw and described what were called animalculæ, living, moving, and multiplying bodies in the tartar from teeth and in animal fecal matter. The first conception of the existence of such microscopic forms cannot be accredited to these observers, since so long ago as in the fourth century B.C. Aristotle suggested the possibility.

As might be expected, these single-celled bodies were not seen until the development of lens-making permitted accurate enlargement. The greatest advances have been made, furthermore, since the perfection of the compound microscope in the early years of the nineteenth century. It is also noteworthy that those who might be considered the founders of this science, so important to physicians, were botanists and chemists. The most important consideration for the early observers was the relation that these minute bodies bore to the spoiling of food and water. Indeed, most physicians of the past and a few of the present have discredited the relation of bacteria to disease.

The first opinion upon the relation of specific disease-producing bacteria came in the middle of the eighteenth century, but such a theory could not be proven until about thirty years ago, when Koch made it possible to separate the various individual bacterial species and enabled us, by a series of postulates, to study the relation of the germs to their particular disease. The great proof of the existence of bacteria came from the man who may be considered the founder of the modern science of bacteriology, Louis Pasteur, a French chemist, who demonstrated beyond question that bacteria produce fermentation, and that fermentable materials, if protected from the air, remain without bacteria. There succeeded to this proof others to the effect that bacteria are ubiquitous, and that they are carried in dust or probably alone by air currents. His experiments also showed that spontaneous generation (the arising of living forms anew from the elements of nature, and not from preëxisting living forms) does not occur. The results of Pasteur's work received practical application also at the hands of Koch and Lister. The former devised methods for the cultivation and study of the individual species and followed this up by discovering the organisms causing tuberculosis, anthrax, and cholera. Lister, shocked by the appalling mortality in the hospitals from gangrene and septic poisoning, established methods by which bacteria from the air and from infected cases were excluded from healthy surgical cases. To him the basic principles of modern antiseptic and aseptic surgery are due.

Throughout all the history of microbiological devel-

opment it has been possible to progress more rapidly and definitely with bacteria than with protozoa. Bacterial life and activity can be controlled very largely now, but as yet little or nothing is known of the important vital activities of the minute animals.

As in the case of bacteria, so the earliest records of protozoa are those of Van Leeuwenhoek's animalculæ. Their natural history has been gradually developed by Jablot, Dujardin, Prowaczek, and Bütschli, and the present leaders in the field, Calkins and Doflein. However, it is only within the last score of years that we have been familiar enough with these lowest animal forms to be sure of their species identity, and we are yet imperfectly informed as to their vital phenomena.

PLACE OF MICROÖRGANISMS IN NATURE.

The studies of the life history of bacteria and protozoa have been the work of botanists, chemists, and physicians. Through this combined effort it has become known that these minute forms are present in or upon or have something to do with the life of all the higher animals and plants. The number of species in all is legion. The number of species pathogenic for animals is but small. A microörganism is pathogenic when it is capable of producing some form of disease in the animal in which it is a parasite. In Chapter III some of the known relations of non-pathogenic bacteria will be discussed. It is sufficient here to emphasize the difference between the so-called parasites and saprophytes. *Parasites* are organisms

capable of living and multiplying within the living animal body, sometimes to its detriment, while *saprophytes* live on dead matter and may be found in nature everywhere—in air, soil, water. The body upon which a parasite lives is called the *host*. There are a few of the parasites that can carry on a saprophytic existence for a short time (facultative parasites), while others (obligate parasites), such as the organism of influenza, demand animal juices for their nutriment. Among the protozoa this obligate parasitism exists quite extensively, and many forms cannot live at all if their normal cycle of life within the animal body be disturbed. Indeed, we know the existence of many species only because they pass through a certain development in insects, then in higher animals and back again in insects; that is, we only recognize them when they produce disease (see Malaria). The saprophytes include the vast number of organisms having important functions among the higher vegetables and the growth of these in soil. It has been suggested that at one time, now long past, all bacteria may have been saprophytic.

The general remarks concerning parasites apply alike to protozoa and bacteria, but in medicine there is at the present time more interest in the bacteria. For this reason only a few diseases caused by protozoa are important.

In order that the positions these unicellular forms occupy in the living world may be known and used for reference to large works, their biological classification is given here. The lowest of the orders among the plants is called Thallophyta. This is divided into Algæ, Lichens, and Fungi. The Fungi are divided

into Hyphomycetes (moulds), Blastomycetes (yeasts), and Schizomycetes (bacteriaceæ or bacteria). This family is divided into Cocci, Bacilli, and Spirilla.

Protozoa, the lowest animal class, present the orders Sarcodina, Mastigophora, and Sporozoa, which contain nearly all the forms of interest in this work.

CHAPTER II.

GENERAL MORPHOLOGY—REPRODUCTION—CHEMICAL AND PHYSICAL PROPERTIES.

GENERAL MORPHOLOGY.

Bacteria (sing., *Bacterium*).—In introducing the subject of morphology a few words as to the technic of observing bacteria will not be amiss. The compound microscope is necessary to all microbiological work. Since this book is devoted to principles, a detailed description of the instrument and its operations would be foreign. Let it suffice to say that the compound microscope is a series of finely ground lenses by which exact pictures in definite magnification can be obtained. An object to be examined is placed upon a glass slide and covered with another but much thinner glass cover. This is laid upon the table of the instrument and the tube holding the lens placed at a proper distance to obtain the best light and clearest picture when viewed through the eye-piece end. For nearly all microbiological observations it is necessary to use a special lens of high magnifying power, called an oil-immersion lens, and to introduce between the lens and the object glass a drop of pure cedar oil into which the lens front dips; this concentrates and filters the light. The microscope is also used to examine the colonies of bacteria. Bacteria are studied either in the fresh living condition

or when stained by appropriate dyes, especially those derived from coal tar, methylene blue and fuchsin.

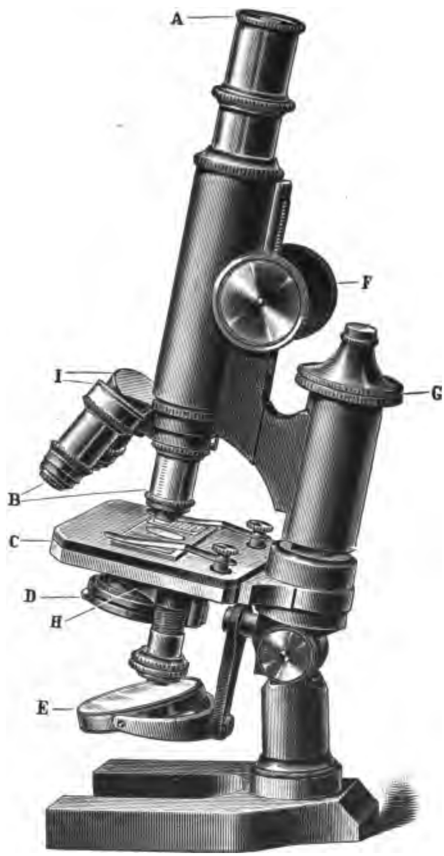


Fig. 1.—Microscope: *A*, ocular or eye-piece; *B*, objective; *C*, stage; *D*, "iris" diaphragm; *E*, reflector; *F*, coarse adjustment; *G*, fine adjustment; *H*, substage condensing apparatus; *I*, nose-piece.

Bacteria are exceedingly small single cells, in their natural state transparent, colorless, and apparently

homogeneous, possessing a very low power of refracting light. They consist of nucleus, cytoplasm, and a wall which is probably a simple superficial condensation of the protoplasm. The ordinary animal or vegetable single cell[1] contains an easily distinguishable body, usually central, called the nucleus, whose function it is to control the cell activities, while the space between this body and cell wall is occupied by protoplasm or cytoplasm, a soft, spongy, or gelatinous matter, which

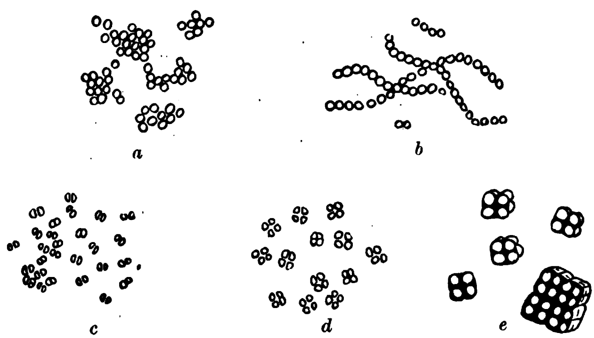


FIG. 2.—*a*, staphylococci; *b*, streptococci; *c*, diplococci; *d*, tetrads; *e*, sarcinæ. (Abbott.)

under very high magnification seems to be made up of a delicate meshwork, within the spaces of which a fluid lies. The nucleus is a denser body usually separated from the cytoplasm by a distinct wall or membrane, and when mashed out is seen to consist of a skein of coarse threads. Into the cytoplasm the nourishment of the cell passes. Of bacteria, either in their natural

[1] See frontispiece for an example of cell. Nearly all living cells are comparable to these leukocytes.

condition or stained for examination, only the nucleus and the wall can be seen, the intervening layer being exceedingly thin.

In shape, bacteria are either spherical, called *cocci* (sing., *coccus*), or straight rods, called *bacilli* (sing., *bacillus*), or curved rods, called *spirilla* (sing., *spiril-*

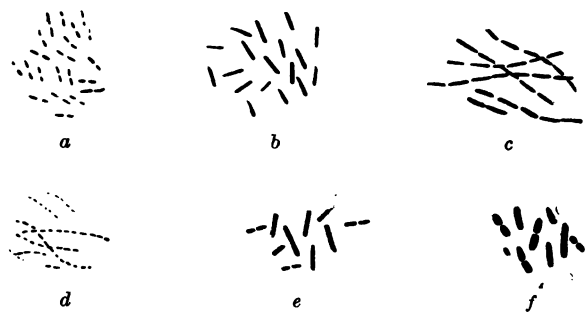


FIG. 3.—*a*, bacilli in pairs; *b*, single bacilli; *c* and *d*, bacilli in threads; *e* and *f*, bacilli of variable morphology. (Abbott.)

FIG. 4.—*a* and *d*, spirilla in short segments and longer threads—the so-called comma forms and spirals; *b*, the forms known as spirochetæ, *c*, the thick spirals sometimes known as vibrios. (Abbott.)

lum). Each shape has slight variations, such as the flattening of the sides when two organisms are apposed. The spirilla are, perhaps, subject to more variations than the others, extending from a simple comma shape to that of a long, wavy spiral when looked at from the side. These last are in reality corkscrews, as they twist

in three planes. In size microörganisms vary considerably. Perhaps a proper conception of some organisms can be obtained when one considers that to cover one square inch in single layer it would require 6,250,000,000 influenza bacilli, a very small organism, or 45,000,000 anthrax bacilli, a bacterium of moderate size. Bacteria are measured in terms of microns. The metric unit, a micron, equals about $\frac{1}{25000}$ of an inch.

REPRODUCTION.

Bacteria.—Bacteria multiply by a simple dividing of their protoplasm. The spherical organisms divide much as one cuts an apple through the poles, the divided halves rapidly assuming the shape of the mother cell. The rods and spirals divide by simple transverse pinching in at about the middle of their long axis.

The new forms may leave each other or may adhere in more or less characteristic groupings, which are taken advantage of in their study and identification. Thus cocci may form pairs or chains, and are known as *diplo-* or *streptococci.* Again, the spheres may produce irregular grape-like bunches or *staphylococci.* These develop in only two planes. Division may occur in the third plane so that packets or cubes of cells result, called *sarcinæ.* Among the rod-shaped bacilli long chains may be formed by a continuous development in the same plane.

A single bacterial cell will divide about every twenty minutes, and Fischer says that from one organism 16,000,000,000 may develop in a single day on suitable

medium. Fortunately, however, foodstuff is used up in the course of multiplication and the waste products of nutritional activity accumulate so that the enormous growth of bacteria is limited. Bacteria can no better live in the presence of their excretions than can animals.

SPECIAL CHARACTERS.

The cell sometimes surrounds itself by an envelope or capsule outside its natural wall, and this is taken advantage of in identification. It is particularly well developed on bacteria when in or lately removed from animal tissues upon which they have been growing. The exact function or importance of these capsules is not known.

Some bacteria are able to move from place to place in a fluid medium, and are called, therefore, *motile.* This is due to the presence of extremely fine filamentous extensions from the cell wall, which upon microscopic examination look like wavy hairs. These are called flagella (sing., *flagellum*). They are arranged either at one end, both ends, or around the whole surface of the cell. They propel the bacterium by a quick waving or lashing motion.

When bacteria are subjected to conditions unfavorable for their life they undergo various changes of size and shape, none of which are very characteristic except the so-called *spore* formation. By this is meant the concentration of the vital powers and some of the physical constituents of the bacterial cell within a very small, homogeneous, highly light-refractive body which is resistant to deleterious agencies and which

may bear little or no resemblance to the parent organism. These spores are not to be considered as evidences

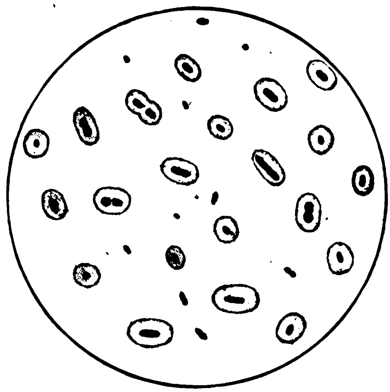


Fig. 5.—Capsule stained by Hiss's method. Rhinoscleroma bacillus. × 1000. (Thro.)

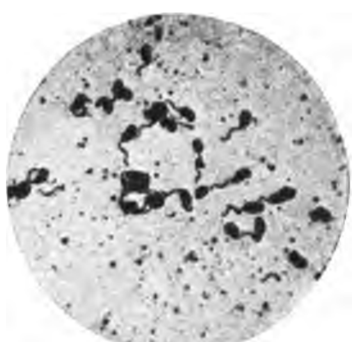


Fig. 6.—Bacilli showing one polar flagellum. (Park.)

of reproduction, but merely as a resting or resistance stage. When conditions of life suitable to the normal

appearance of the bacterium are resumed the spore will develop into the same kind of organism as that from which it came. This spore forming is seen

FIG. 7.—Bacilli showing multiple flagella. (Park.)

FIG. 8.—Unstained spores in slightly distended bacilli. (The spores are the light oval spaces in the heavily stained bacilli.) (Park.)

among bacilli and spirilla, probably never among the cocci. As a rule, only one spore is found in each bacterial cell. These spore formations assist in identification. The practical importance of spores is that

they resist the agencies quickly fatal to the adult or vegetative forms. Bacteria in their ordinary development are said to be vegetating, and we must differentiate between the vegetative stage and the spore-forming stage.

Protozoa (sing., *Protozoön*).—Protozoa are single-cell animals of protean shape. They vary in size from that of the smallest bacterium to nearly one-quarter of an inch in length. They are made up of a fairly well-

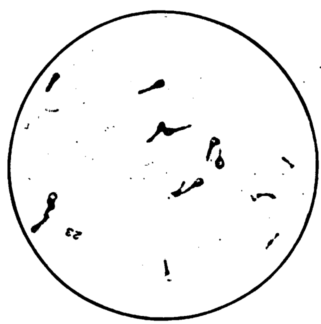


FIG. 9.—Unstained spores in distended ends of bacilli. (Park.)

formed wall which may have an appreciable thickness or be merely an immeasurable line. Their cytoplasm, unlike that of bacteria, is usually far in excess of the nucleus. It is sometimes homogeneous, at other times full of granules, septa, or a dividing meshwork. The nucleus is a complex body varying from a simple, bladder-like mass to a dense and intricately wound skein. The vital activity of the protozoan cell seems to lie in a small body, usually in the protoplasm, but originating from the nucleus, called the centrosome.

Protozoa move by several methods. Some possess short, delicate, hair-like projections from the wall, which exhibit a slow, wavy motion. These are cilia. Others have one, two, or three long coarser threads, the flagella (sing., *flagellum*) arising from various parts of the structure and producing locomotion by a thrashing or whip-like motion. Perhaps the simplest and surely the most primitive form of motion is to be seen in what are called pseudopods or false feet, a phenomenon characteristic of the amebæ. This is a pushing out or budding of a portion of the cell wall into which the cytoplasm of the protozoön flow, enlarging the false foot until it embraces all the contents of the cell. The space formerly occupied by the protozoön is vacated, the cell having moved to a position directed by the pseudopod. In some protozoa a portion of the body has muscular power and drives the organism. Again, a portion of the cell wall may be fitted with a sucking apparatus, serving either to drive the protozoön or to attach it to another body. Protozoa gain their food by simple absorption through the wall or by possessing definite vacuoles or openings for this purpose. Excretion takes place the same way.

Reproduction may occur by simple division as in bacteria. Protozoa may divide by simple budding with breaking off of the smaller piece similar to the first stages of the pseudopod. The higher protozoa go through a complicated process of division such as is seen in the higher animal cells, or there may be male and female elements with conjugation.

CHEMICAL AND PHYSICAL PROPERTIES.

Bacteria.—Chemically the bacterial body is composed chiefly of water (80 to 90 per cent.), the remaining part being made up of protein (see below), fatty matters, including waxes, a trace of the carbohydrates (sugars and starches), and inorganic material. The cellulose supposed to be characteristic of vegetable cells is present in very small quantities. The largest part of the solid matter is comparable to the organic substances which form the most important foodstuff for animals, the proteins. Chlorides and phosphates of the lighter metals form the inorganic salts.

The wall of the bacterial cell permits the passage of fluids containing foodstuffs, and is therefore comparable to the wall of other vegetable and animal cells.

Protozoa.—The chemical composition is probably like that of bacteria, although little is known of it. Their vital activities are influenced by physical conditions, as is the case with all animate beings. They require moisture for their full development, but may live for indefinite times when it is at a minimum. A definite temperature is demanded by each species or genus for its full activity. They are susceptible to high degrees and remain quiescent in nature in the cold for a long time. Desiccation of the germinating forms is usually fatal, but when in sporulation or encystment drying is more easily withstood. Light is not absolutely essential for the growth of protozoa, but they are usually attracted or repelled by it; that is, few if any are indifferent to luminosity.

CHAPTER III.

GENERAL BIOLOGY, INCLUDING THE CHEMICAL CHANGES WROUGHT BY BACTERIA.

Bacteria.—The bacteria with which the physician is chiefly concerned as disease-producing are but a very small number when compared with the multitude of species in nature. The lay mind is apt to consider any germ as noxious, but instead of this it can be said that without the activity of many saprophytes, life on the earth would soon be extinct. Animals require organic material from plants for their nourishment, but their cells do *not* possess the power to put together (synthesize) the elementary constituents necessary for their complex cell composition. Bacteria *have* the power both of breaking down and building up; that is, they may reduce some compounds to their elements or build up elements into more complex substances.

Perhaps the most striking examples of this property are to be found among the earth organisms, some of which break down organic matter into ammonia and liberate nitrogen, others then taking up this gas from the atmosphere and combining it with other elements in a form that plants can assimilate.

The products of their breaking down and building up are utilized by plants and are presented to animals

as food in such a form that the animals can use them for their cell needs. It is not the purpose of this book to dwell upon this abstract matter of general biology, but the principles of the activities of non-pathogenic bacteria can well be seen in those inhabiting the intestines.

It may be possible for a human being to live without bacteria in the alimentary tract, but some of those present are beneficial in effect. A perfectly healthy young animal may be born without bacteria in the intestines, but organisms soon gain entrance with air and food, since practically no object in the world of life is free of them. The ordinary saprophytes of the intestinal tract assist in making fats more easily assimilable, and destroy some of the pathogenic bacteria.

Bacteria require for their life moisture, some degree of heat, and a variety of foodstuffs.

The amount of moisture is of little importance provided sufficient is available to make up the physical bulk of the organism and assist in the passage of foodstuffs through the cell wall. The substances used by bacteria in nutrition are dissolved or suspended in water. Temperature requirements are, however, more exact, and every class has its own preferred degree. Those which commonly inhabit the animal body require a temperature of 98° F. (37° C.), while those living naturally in soil or water thrive best at 60° to 70° F. (15°–21° C.). Foodstuffs must contain the same substances as for the growth of other plants, but the organisms which infest the animal body, grow most luxuriantly when animal tissue or fluid is present.

The reaction of the material upon which they are growing is of no small importance. Nearly all bacteria live best when the medium is about neutral or of faintly alkaline or acid reaction. All need carbon, oxygen, nitrogen, hydrogen, and salts. Some organisms cannot live in the presence of free oxygen, but obtain it as they need it by breaking up, or reducing, substances containing this element. These are called *anaërobic* bacteria, such as the tetanus bacillus. Micro-organisms that can live in the presence of atmospheric oxygen are called *aërobic*. Most pathogenic forms have this power.

The foodstuffs presented to bacteria are seldom in a pure state, so that the power of breaking up the material on which they are existing into the elements necessary for the life of the cell has to be done by some process of cellular activity. To do this, bacteria form what are called *enzymes* or *ferments*. An enzyme or ferment is a product capable of changing a chemical combination without itself entering into the product of this change. The bacterial enzymes are comparable to the enzymes found in the digestive juices of the human alimentary canal. There are many kinds of ferments, each having the power of breaking up certain chemical substances. There are ferments splitting up sugars and starches and fats and proteids, and the result of this splitting is simpler in composition than the substance split, thus making it easier of use as food. The ferment activity of bacteria is just like that of yeasts which are used in the industries, especially that of spirituous liquor-making. In this case the organisms and their enzymes are capable of splitting

sugar with the production of ethyl alcohol, and specific species or strains are kept by vineyards, distilleries, and breweries for the peculiar kind of fermentation desired.

Some bacteria have the property of producing light (phosphorescent bacteria on sea water), and many form coloring matter both in nature and when grown artificially (colored mould on preserves).

The effect of saprophytes upon pathogenic bacteria in the intestine is that they sometimes destroy the latter. Metchnikoff found that certain bacteria produced so much acid, chiefly lactic acid, that many other bacteria could not live in their presence. He took advantage of this to assist in the treatment of certain cases of putrefaction in the intestinal tract. Bacteria also may produce various simpler products in the course of their enzyme action. Now it happens that some of the bacteria in the intestinal tract, perhaps under the stimulation of irregularity of function, may produce too much fermentation of sugars and starches or too great breaking down of the most important foodstuff, the proteids. From this improper breaking down and absorption of its products comes the so-called intestinal intoxication.[1] Metchnikoff's experiments have shown that the high acid produced by certain saprophytes, the lactic acid germs in particular, is inimical to the producers of this disturbance. In practice, therefore, cultures of these bacteria are administered by mouth.

[1] Auto-intoxication is a term sometimes given to this condition, but it is incorrect and should be limited to disease due to some functional disorder of digestion.

Other activities of bacteria and their enzymes are seen in the precipitation and curdling of cream known as cheese. Again, the specific flavor of tobacco and opium for the pipe is due to bacteria. In the production of indigo and in the preparation of hides for tanning, bacterial enzymes play an important part.

Protozoa.—Of the saprophytes of protozoa practically nothing is known. Protozoa are parasitic either by the mechanical irritation caused by their presence or by taking their nutriment to the damage of their host. Malaria organisms, for example, may block capillaries and shut off blood supply, although they also disturb the nourishment of the tissues further by destroying red blood cells, which carry oxygen. For optimum development they require, as in the case of bacteria, moisture and a suitable reaction, but rather a higher temperature and more complicated food, as a rule.

CHAPTER IV.

METHODS OF STUDYING MICROÖRGANISMS —STERILIZATION BY HEAT.

LABORATORY TECHNIC.

IN the study of microscopic beings it has been necessary to elaborate a special technic which will supply the requirements of life. Before the epoch-making work of Koch it was necessary to cultivate microörganisms upon broth or bread, and there was little known as to the exact composition of the medium. Koch showed how to control the growth of bacteria in the laboratory. To Pasteur and Kohn credit also is due for the standardizing of the foodstuffs upon which bacteria are cultivated. Let us assume that we have been given a culture of bacteria to study. Since the identification of species is not a part of a nurse's duty it is not necessary to discuss the separation of many germs in a mixture. Bacteria are transferred from one place to another, as, for example, from one culture tube to another or to a glass slide, by means of a piece of platinum wire set into a handle. This metal will withstand great heat and can be sterilized in the flame of a Bunsen burner after every using. The Bunsen burner is an apparatus so arranged that air is thoroughly mixed with the gas and the mixture is completely burned. Starting out with the material

from which this single organism comes the bacteriologist spreads it on a glass slide and colors it by certain aniline or vegetable dyes, of which there is a large number. It is practically impossible certainly to identify any bacterium by a simple examination of a stained preparation under the microscope. The

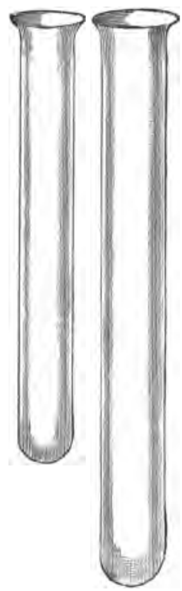


FIG. 10.—Culture tubes. (Park.)

observer, however, does form a tentative opinion as to its probable nature, and proceeds to introduce some of the material into a nutrient medium which he considers best adapted to its development. Among these are broth, milk, potato, coagulated blood serum, and broth stiffened (when cool) with gelatin and the

Japanese moss, agar-agar. These foodstuffs, called media for short (sing., *medium*) are kept in test-tubes or flasks. The worker may also spread into flat glass plates (Petri plates) some of this stiffened broth in order first to see in what form the germs will grow as

FIG. 11.—Showing certain macroscopic characteristics of colonies. Natural size. (Abbott.)

"colonies," and secondly, to see that only one kind of colony, therefore only one kind of germ, is present (Fig. 11). In other words, he wishes to know if his culture be "pure." This means of obtaining a pure culture depends upon the fact that from each single

organism smeared upon a plate only one kind of colony of organisms will develop. It is the custom to put all material to be examined upon plates of nutrient medium to start with, by which process the worker at once has before him evidence to show how many kinds of bacteria are present and the means of isolating

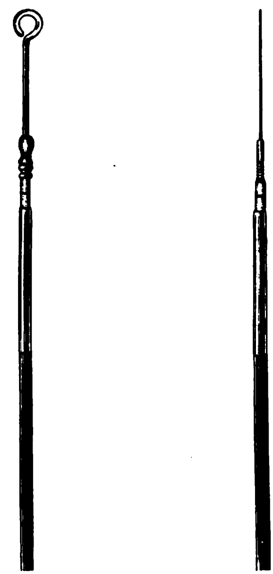
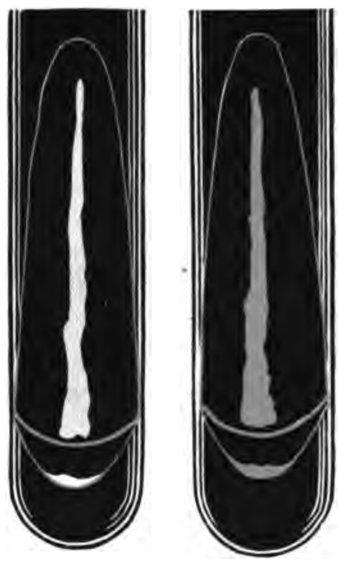


FIG. 12.—Platinum needle and loop. (Park.)

pure cultures after the first inoculation. These tubes and plates are placed at body temperature (98° F. or 37.5° C.) in the incubator. An incubator is a doubly insulated metal box, heated by gas or electricity and controlled by an automatic device by which the temperature is kept constantly where desired. Practically

PLATE II



Cultures of Bacteria. (Besson.)

The jellies upon which the pure cultures are grown, are hardened in test-tubes in a slanting position. The bacteria are then spread along the oblique surfaces and grow in bands or streaks as shown here.

all pathogenic bacteria develop best at this temperature. The bacteria of the soil and water probably grow best at about 70° F. or 20° C. After these tubes and plates have been "incubated" for twenty-four or forty-eight hours the bacteriologist observes them

Fig. 13.—Method of transferring cultures from one tube to another. (Hiss and Zinsser.)

and takes note of the evidences of growth. He will make stained preparations for microscopic observation and note the morphology of the plant. Many stains are in use for demonstrating various characteristics. He will also prepare what is known as a "hanging drop." This consists of a drop of fluid broth culture upon a

thin inverted glass (Fig. 14). He will discover from this preparation under the microscope the presence of motility and the manner of division of the bacteria. From his tube cultures he chiefly finds out whether the bacteria develop enzymes. To the solid media (agar-agar) he may add various sugars to discover the fermentative powers of the bacterium. The fermentative powers may also be observed when the germs grow upon bouillon containing the sugars. This broth is placed in an apparatus called a fermentation tube so arranged that the percentage of sugar broken up by the bacteria can be estimated. When he shall have made all his observations he will sum up his results and identify according to the classification of bacteriologists.

FIG. 14.—Hollow slide with cover-glass. (Park.)

The presence of bacteria is searched for in pus and diseased tissues by making a smear from the fluid or affected part upon glass slides and treating it with certain dyes. Before the dyestuff is applied the smear must be *fixed* by heat or alcohol or formaldehyde. This is for the purpose of killing the albuminous material, keeping it exactly as it was when removed from the body, and rendering it susceptible of taking up and permanently retaining stains, a property living tissues and fluid possess to a very slight degree. Once fixed and stained, examination will reveal the bacteria present, and the observer can form an opinion of the probable nature of the infection. Reference is

frequently made in the text to Gram's stain, and it is desirable that the reader be familiar with the term and its significance. It is a combination of aniline oil, water, and gentian violet, which stain can be fixed into some bacteria by after-treatment with iodin solution, so that alcohol will not wash it out. The test is of great importance in determining certain species.

Animal Inoculation.—Another method of studying bacteria is by injecting them into susceptible animals. Thus can be discovered their power of producing disease, its severity, called virulence, and the nature of their action. When the presence of bacteria in morbid matter cannot be demonstrated by stain or by cultural methods, it may sometimes be shown by injecting the suspected material into animals. If the animal fall sick or die one can then obtain cultures of the germs for study. The value of this method of discovering bacteria is increased by the development of changes in the animal's organs peculiar to certain germs. Thus the tubercle bacillus, an organism not easy to find by direct examination, produces definite alterations of organs and special kinds of inflammation by which its presence is indicated and from which it can be obtained. This is also true for other bacteria—streptococci, anthrax, and glanders bacilli.

Protozoa.—The study of protozoa varies according to the source. The parasite of malaria may be found by direct microscopic examination of the fresh blood. This is also true of the organism of sleeping sickness. The protozoa causing dysentery require the maintenance of a definite temperature for a long time, and

this is achieved by the use of a hollow slide filled with warm water. These organisms are cultivated artificially only with great difficulty, and the use of special stains is required for the purpose of practical clinical diagnosis.

STERILIZATION.

For a better understanding of the technic of laboratory procedure, the preparation of the foodstuffs or media on which bacteria thrive will be briefly considered. They are prepared from meat or its extracts, a substance called peptone, and salt, and adjusted to a suitable reaction of weak alkalinity, according to carefully worked-out formulæ, which are the result of long experimentation. They are stored or distributed in glassware, which is of the non-corrosive type. This glassware is cleaned with soap and water, sand or alcohol, and rinsed with distilled water. It is then sterilized by hot air. The glassware and media are sterilized because bacteria are ubiquitous, and apparatus and foodstuffs wholly free from microörganisms are necessary in bacteriological technic. In no other way can one be sure of obtaining germs in pure culture, that is, only one kind. After the medium has been put into the glassware, steam sterilization is used; dry heat is ineffectual and destroys the medium. The best method of sterilization is by the autoclave or pressure boiler, since all organisms are killed by one atmosphere of pressure to the square inch in addition to the ordinary atmospheric pressure. Because of the delicacy of some of the nutrient media it is, however, necessary to sterilize these

at the usual pressure of the atmosphere in streaming steam. For this purpose a double-jacketed boiler with the steam introduced into the inner chamber (Arnold steam sterilizer) is used.

FIG. 15.—Erlenmeyer flask.

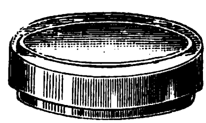


FIG. 16.—Petri dish.

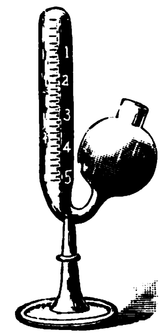
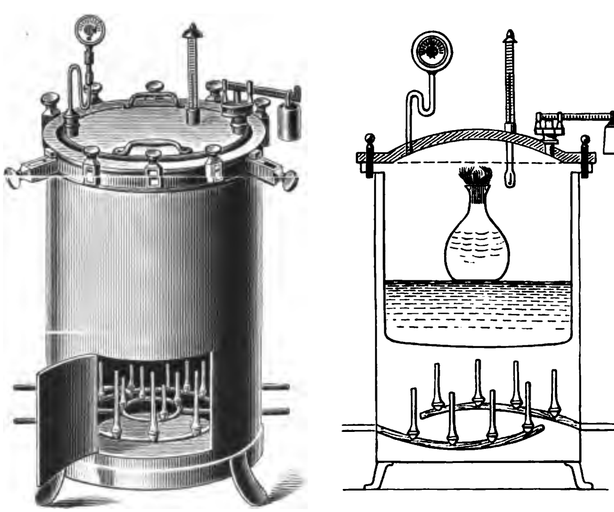


FIG. 17.—Fermentation tube.



A *B*

FIG. 18.—Autoclave, pattern of Wiesnegg: *A*, external appearance; *B*, section.

While this sufficiently indicates the uses of sterilization for the preparation of food for bacteria, a few words upon sterilization in general are necessary. This term is usually reserved for the killing of bacteria by means of heat, either dry or moist. For the killing of bacteria by other means see Chapter V.

The most widely applicable and efficient physical agent *for sterilization* is *heat*. A certain amount of

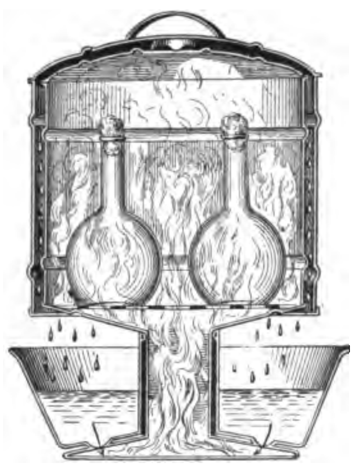


FIG. 19.—Arnold steam sterilizer.

heat is necessary for the life of bacteria, but there are certain temperatures beyond which they cease to live. While 38° C. or 98.5° F. is their *optimum* or most suitable temperature, they find it increasingly difficult to live as the temperature rises to 50° C. or 122° F. Beginning there and extending to 62° C. or 144° F. the commoner pathogenic organisms are killed by ten minutes' exposure. For example, the typhoid bacillus dies when

heated to 56° C. or 133° F. for ten minutes, and the pneumonia coccus at 52° C. or 126° F. for ten minutes. The tubercle bacillus is much more resistant and requires from ten to twenty minutes' exposure at 70° C. or 158° F., varying directly with the density of the medium in which it is. The spore-forming organisms are characterized by a vastly greater resistance. This

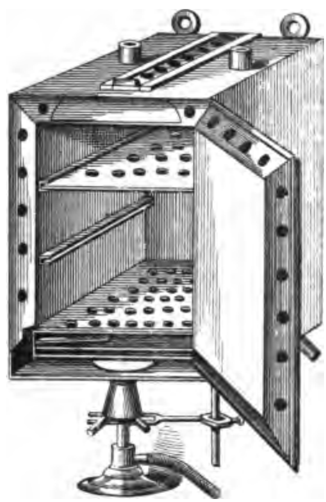


Fig. 20.—Laboratory hot-air sterilizer.

is due to the peculiar property of spores of resisting deleterious agencies.

Low temperatures are much less destructive than high ones. The typhoid and diphtheria organisms may resist 200° below zero C. or −300° F., while some of the more delicate organisms quickly die at zero.

In sterilization that method is chosen which will do the least damage to any object to be conserved.

Simple boiling should be undertaken whenever practicable, and immersion for five minutes in boiling water will destroy the vegetative forms of all bacteria. For spores, however, at least of the disease-producing kind, two hours is necessary. It is advisable to add 1 per cent. of sodium carbonate to the water. This assists in killing of spores, and metal objects are not so apt to rust. This simple boiling for ten minutes is sufficient for dry cleaned syringes, trays, dishes, and surgical instruments in the absence of infective material known to contain spores. Sterilization in live steam is the most practical method of killing bacteria, as it can be carried out in the kitchen. In the laboratory it is done by the Arnold sterilizer (Fig. 19). It is the custom to employ what is called fractional sterilization. This method is the exposure of the material to be disinfected to the temperature of 100° C. or 212° F., which is the temperature reached by the steam in the inner chamber, for fifteen minutes on three successive days. On the first occasion vegetative forms are killed and the spores remaining are permitted to pass into the vegetative state overnight. On the second occasion these will then be killed. A third exposure insures sterility. The exposure of fifteen minutes is considered to begin when the steam is up and the thermometer registers 100°. The foregoing method is practicable for dressings and rubber gloves. For sterilization of objects not injured by pressure the boiler or autoclave is used. The principle of this apparatus is that steam is admitted into the sterilizing chamber, the air having been expelled by heating of the walls and displacement by the entering steam. When no air is present the pressure within the appa-

ratus rises and steam penetrates all permeable objects. When the steam escapes and air enters, moisture is absorbed and the objects become dry. By this means as much as two extra atmospheric pressures can be run up, which will be equivalent to 34.5° C. or 74° F. above the boiling point. After starting up steam the apparatus should never be tightly closed at the safety valve until all air is expelled. This method is particularly adapted to the sterilization of dressings and infected cast-off clothing. Hot air is suitable for dried glassware and articles injured by moisture, and can be used for domestic sterilization by exposing the articles in the household oven. It is less efficient than moist heat. This is due to the fact that organic substances are less easily coagulated in a dried condition. Spores are more resistant also, as, for example, the anthrax spore, which requires an exposure of three hours at 140° C. or 284° F. dry heat. Hot, dry air penetrates less easily than hot moisture. Burning is the best of all methods, and should be used for everything which can be spared, handkerchiefs, dressings, and objects like magazines from the sick room.

The two thermometric scales are explained as follows:

F. = Fahrenheit, the ordinary scale used in this country. Water just at the freezing point registers 32° F., while just at the boiling point registers 212° F. The zero has no relation to physical changes.

C. = Centigrade, the French system. Water just at the freezing point is 0° C., and just at boiling point is 100° C.

The 100 degrees in the Centigrade scale is equal to the 180° between 32° and 212° in the Fahrenheit scale.

To change one system to the other proceed as follows:

From Fahrenheit to Centigrade: Given degree F. $-32 \div 9 \times 5 =$ same degree in Centigrade scale. Example: 50° F. $-32 = 18 \div 9 = 2 \times 5 = 10$. Therefore 50° F. = 10° C.

From Centigrade to Fahrenheit: Given degree C. $\div 5 \times 9 + 32 =$ same degree in Fahrenheit scale. Example: 10° C. $\div 5 = 2 \times 9 = 18 + 32 = 50$° F.

CHAPTER V.

DESTRUCTION OF BACTERIA BY CHEMICALS AND THEIR PRACTICAL USE.

It has been shown how bacteria can be killed by heat, and now the chemical methods of destroying infective material will be discussed, and how this may be done practically. Chemicals either in solution or as gas are supposed to kill bacteria by one of several methods. The whole bacterial body may be destroyed or the protoplasm may be entered by a diffusion of the substance through the cell wall with consequent coagulation or solution. It is said also that the rapid withdrawal of water absorbed by some salts may be fatal to the microörganism.

There is some confusion as to the terms used for chemical bacteria-killing, and for this reason it may be well to start out with Park's classification. (1) *Attenuation* is when the pathogenic or vital functions of the bacteria are temporarily diminished. (2) *Antiseptic* action is when the bacteria are not able to multiply but are not destroyed; they will reproduce when suitable conditions for life are restored. (3) *Incomplete sterilization* or disinfection is when the vegetative forms but not the spores are destroyed. (4) *Sterilization* or *disinfection* is when both vegetative and spore forms are destroyed; this implies also the destruction of any products of bacteria capable of producing disease.

Practical disinfection must provide not only for superficial action but also for penetrative, and a disinfectant should be selected which will act as deeply as possible. Formaldehyde gas or its solution has a high penetrating power and is therefore commonly used for the disinfection of rooms, mattresses, and clothing after infectious diseases. Simple air disinfection is of practically no value, since disease viruses do not live long in the air but may settle upon surfaces where they can be killed either by gaseous disinfectants or direct application of germicides. All disinfection is rendered more efficacious by a good cleansing and a liberal supply of "elbow grease."

A chemical is tested for its antibacterial properties in several ways, chief among which is the immersion of some of the pure bacterial growth in solutions of various strengths of the chemicals.

Some of the individual disinfectants are:

Bichloride of Mercury (corrosive sublimate).—This is soluble in 16 parts of cold water. One part in 100,000 inhibits the growth of most bacteria. In twice that strength many kinds are killed in a few minutes. Spores are destroyed in 1 to 500 solution in water within one hour. In order to obtain the best results with this corrosive sublimate it is necessary to have an acid reaction, for which reason most of the tablets now on the market are made up with an acid having no effect upon the mercury salt. The acid reaction is especially demanded when the material to be disinfected is pus, blood, feces, or the like, substances containing albumin which combines with the mercury and renders it inert. It is wise to use a strength of 1 to

500 for one-half hour when any such organic material is present. The disadvantages of bichloride are, beside that mentioned above, that it corrodes metals and is rather hard on the skin. It is well to add some coloring matter to the solution for the purpose of identification, since this is a rapidly acting, corrosive, deadly poison. Great care should be used in keeping the tablets and solutions, as many accidents have occurred. Being odorless it attracts no attention.

Silver Nitrate.—Park says that this salt has one-fourth the value of the preceding as a disinfectant, but nearly the same value in restraining bacterial growth. It is not a very practical disinfectant, because of its destructive action on the skin and fabrics, but it can be used with value in diphtheria. Solutions should be freshly prepared in 1–2 per cent. strength.

Copper Sulphate.—This chemical is potent against typhoid in water in the presence of little organic material in the strength of 1 to 400,000 in twenty-four hours.

Sodium Hydroxide (caustic soda).—This substance is very destructive to fabric and to the skin, but kills, in the strength of 1 to 100, vegetative bacteria in a few minutes, or spores are destroyed by 4 per cent. solution in forty-five minutes.

Sodium Carbonate.—This chemical, advantageous for boiling instruments, kills vegetative forms in 5 per cent. solution very quickly, or spores in boiling water in about five minutes.

"Chloride of Lime" (chlorinated lime).—This chemical is also known as bleaching powder. There is a difference of opinion as to its composition. Its power de-

pends upon the liberation of free chlorine gas, which rapidly disappears when the lime is exposed, so that the dry material must be kept covered and solutions prepared as needed. It is destructive to fabrics. A 1 per cent. solution will kill all non-spore-bearing organisms in five minutes, and a 5 per cent. solution destroys spores in one hour. *Calcium hydroxide,* made by adding water to quicklime, is efficient against typhoid bacilli in feces when a 20 per cent. solution is added to thoroughly mixed feces in equal parts and exposed one hour.

Dr. Daken, working for the British Army, has found that the addition of sodium carbonate to a solution of chlorinated lime, which mixture is neutralized by boric acid, forms a highly efficient germicide for wounds. It is not destructive to tissues, will penetrate, and may be used in high concentration, 1 to 20. Its value lies in the hypochlorous acid which is liberated in the tissues.

Carbolic Acid or Phenol.—This is a crystalline solid which softens when exposed to the air. It is soluble in 15 parts of water. It must be thoroughly mixed with material to be disinfected. It is not destructive to fabrics or colors. It acts best at about the body temperature. It is not much affected by the presence of organic substances. A 5 per cent. solution kills spores in a few hours, and 1 to 1000 inhibits the growth of all bacteria and may be considered as an antiseptic; 3 per cent. solutions kill the pus cocci in one minute.

Cresols.—These are thick, sticky, brown fluids related to carbolic acid. They make a milky emulsion with water. The best-known ones are tricresol, creolin,

and lysol. The two latter are probably the best, as they mix with water fairly well. All these substances in 5 per cent. emulsion kill the ordinary bacteria within three minutes and the spore-formers within an hour.

Other Disinfectants.—Ordinary alcohol kills vegetative forms in a few hours. A 70 per cent. alcohol is perhaps the most potent. It has lately been shown that for surface disinfection no method is superior to 10 per cent. iodine in 70 per cent. alcohol. Practical surgical work seems to indicate that for skin disinfection before operation all bacteria are destroyed in the epidermis. Some defenders of this method maintain that its penetrating powers exceed any other known practical disinfectant. The method, while undoubtedly excellent, must remain for a while *sub judice* before one can accept this statement. Chloroform kills vegetative bacteria and restrains spores, even in small quantities. Ordinary soap is a good disinfectant, particularly by its solvent power on the simple organic substances. Its effect is increased by the addition of common washing soda.

Acids.—The strong mineral acids are not practical disinfectants, but nevertheless are very efficient. Boric acid kills the less resistant organisms in a 2 per cent. solution, but only after some hours' exposure.

Gaseous Disinfectants.—There are only three of practical value. They are sulphur dioxide, oxygen from hydrogen dioxide, and formaldehyde. Chlorine is not included here because it is seldom used in its pure state, since it is highly poisonous and destructive; it is, however, eminently efficient.

Sulphur Dioxide.—Sulphur dioxide is used for hospitals, apartments, and ships, and is especially well suited to the destruction of rats and insects. It is more efficient when there is considerable moisture in the air. When conditions are suitable for disinfection, anthrax bacilli in the vegetative condition are destroyed in thirty minutes when there is 1 volume per cent. of the gas in the given space. "Four pounds of sulphur burned for each 1000 cubic feet will give an excess of gas." Some water should be sprayed in the room or an open vessel containing water should be there. It has been suggested that the sulphur candles of commerce be burned, resting on a brick in a bucket of water.

Dioxide of Hydrogen.—A 2 per cent. solution of the pure substance will kill anthrax spores within three hours. In 20 per cent. solution it kills vegetative bacteria, pus cocci, and the like in a few minutes. Its activity depends upon the liberation of free oxygen. It should be kept tightly sealed, since it easily gives up this gas.

This substance has been widely used in the great European war, in the treatment of gas bacillus infection, its beneficial effects being widely commented upon and attributed to the liberation of oxygen in the tissues with bactericidal effect. It seems to me that this cannot be all the reason, as this gas is soon utilized by the tissues. A much more probable explanation is that the liberation of bubbles tears the tissues into large webbed meshes and allows other disinfectants free play or permits a penetration of atmospheric oxygen inimical to the anaërobic germs.

Formaldehyde.—This is a gas, but is most commonly seen as a solution ordinarily known under its trade name formalin. This contains from 35 to 40 per cent. of the gas and also some wood alcohol. The gas has an affinity for many organic substances, among them some of the dyes, but fabrics are not affected. Of the metals, iron and steel are attacked after long exposure in the presence of moisture. By reason of its affinity for organic substances it is a good deodorizer and disinfectant chiefly because it forms new insoluble odorless compounds.

It is not very irritant when taken into the stomach, but its vapors cause considerable annoyance in the eyes, nose, and mouth. The lower animals resist it considerably, but insects are not affected. It is more effective in the presence of moisture and when the temperature is high, up to 120° F. If these conditions cannot be obtained the exposure must be longer. Two and one-half per cent. by volume of the aqueous solution or 1 per cent. by volume of gas are sufficient to destroy fresh virulent cultures of the common non-spore-bearing bacteria in a few minutes.

PRACTICAL APPLICATION OF DISINFECTION.

Stock Solutions.—As given by Park these can be made as follows: 6 ounces of carbolic acid in 1 gallon of hot water—this is about a 5 per cent. solution. It is milky at first and must be stirred thoroughly. The addition of a small amount of glycerin keeps the carbolic acid in solution and probably assists in disin-

fection, in part by absorbing water, in part by making a coating on objects and holding the phenol.

Bichloride solution: 60 grains of pulverized bichloride and 2 tablespoonfuls of common salt to 1 gallon of hot water = 1 to 1000. Store in glass or earthen vessels. Agate will answer. It is well to color the liquid or to have a prominent label indicating poison.

Milk of lime: 1 quart of dry, freshly slaked lime to 4 or 5 quarts of water. Lime is slaked by pouring a small quantity of water on a lump of quicklime. The lime becomes hot, crumbles, and as the slaking is completed a white powder results.

Formalin solution: 1 part of formalin to 10 of water is equivalent to 5 per cent. of carbolic acid.

Cleansing of Skin.—For this purpose a 1 to 1000 carbolic or 1 to 1,000 bichloride should be used, allowing it to act for at least two minutes. Following this there should be scrubbing with soap and water with a soft brush. It is unwise to roughen the skin with stiff bristles. The newer methods, using iodine-alcohol, require only simple soap and water washing and then a few applications of the solutions to the skin to be disinfected, allowing each application to dry before proceeding.

Fabrics.—Soiled fabrics should be soaked in carbolic, formalin, or bichloride in this order of preference for at least two hours. Mattresses should be exposed to the sun or removed by health authorities for disinfection. After soaking infected goods in these solutions they should be boiled for at least twenty minutes, preferably with soap. Materials from the sick-room

should never be carried to other parts of the building in a dry state.

Utensils.—Utensils should be soaked in the solutions and then boiled.

Urine, Feces, and Sputum.—Urine, feces, and sputum should be received in glass, earthen, or agate vessels already containing carbolic acid solution, milk of lime, or formalin, and they should be allowed to remain for at least one hour. It is well to cover the vessel.

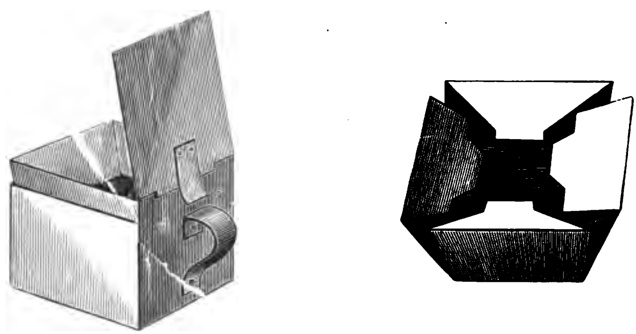


FIG. 21.—Sanitary spit-cups.

In the absence of disinfectants, discharges should be burned or boiled for one-half hour. The solid masses of feces should be broken up in order to permit the proper penetration of solutions.

Tuberculous Sputum.—Perhaps nothing is so important as the disinfection of tuberculous sputum, as it is the chief means of the transmission of tuberculosis. It should be received preferably in a pasteboard cup within a metal holder, the former being burned. It may be caught in metal or agate cups containing

carbolic or milk of lime solution. If caught in handkerchiefs they should be burned. The hands must be washed in a disinfectant after catching sputum in a handkerchief.

Water-closets and Sinks.—They should not receive infective materials until these shall have been thoroughly disinfected. To disinfect sinks and water-closets, chlorinated lime, cresols, and carbolic acid are the best.

Disinfection of Rooms and Houses.—The disinfection of rooms and their contents, while not necessarily the nurse's duty, deserves some mention. In case of infectious disease, physical cleaning must be left until after chemical disinfection shall have been done. It is then carried out on the ordinary plan of house-cleaning. The practical methods of house-disinfection today have narrowed down to formaldehyde. There are many forms of apparatus and several methods of producing this gas, but whatever the procedure, certain conditions must be observed. The temperature of the air in the room must not be less than 100° F., and there should be a high percentage of moisture. The most common method now used for the production of formaldehyde gas is the mixture of 1 pint of commercial formalin and 10 ounces of small crystals of potassium permanganate in an open vessel for each 1000 cubic feet of air space. These are usually mixed in the centre of the room in a tall metal case of some sort, surrounded by water, which serves the purpose of catching any of the mixture which bubbles over or extinguishing fire which sometimes occurs spontaneously. The cracks of doors and windows are always sealed by

pasting strips of paper over them, and the room left sealed for twenty-four hours; this saves much of the vapor for disinfection and protects inmates of other parts of the house. Any remaining odor may be displaced by sprinkling ammonia about.

Instruments.—Instruments, including syringes, may be boiled for five minutes in a 1 per cent. solution of washing soda. Knives, however, should be kept in alcohol. Gauze should be sterilized at 120° C. or 248° F. and 15 pounds' pressure.

Pasteurization.—This consists in the heating of a substance, milk usually, to a temperature below the boiling point, usually 140° F. to 56° C., which kills the non-spore-bearing bacilli, and holding there for a few minutes. It is then cooled as rapidly as possible to a point at which bacteria do not usually multiply, that of the ice-chest. This does not sterilize the substance, but in the case of milk may render it more likely to spoil afterward if not properly taken care of.

Sunlight.—A most admirable disinfectant is sunlight. Direct sunlight will eventually kill all bacteria, and it is wise to expose materials from the sick-room, whether from an infectious case or not, to as much sunlight as possible.

CHAPTER VI.

THE RELATION OF BACTERIA TO DISEASE —IMMUNITY.

The difference between saprophytes and parasites has already been emphasized, and incidently it has been learned that the latter may for a short time lead a life comparable to that of the former. The organisms that produce disease, pathogenic, are everywhere, particularly in the crowded life of cities. Not only are they on the objects of our environment, but within the entrances to the body. Sometimes organisms are found in the mouth and nose which are classed as pathogenic. Certain organisms are present invariably in the alimentary canal, and under proper circumstances can produce disease. It is often difficult, therefore, to determine precisely how a bacterium enters the body and produces the disease, because it is evident that some factors other than the simple presence of microörganisms are necessary to develop what is termed sickness. A disease might be fairly well described as the subjective (experienced by the patient) and objective (perceived by the physician) expression of the forces exerted by the bacteria and the defense presented by the body.

These two forces must now be considered, and following the natural sequence, bacteria will be traced in their usual seats upon and within the human body,

in their course past the primary defences and their manner of awakening the secondary or peculiar immunity resistances which the human system presents. Bacteria gain entrance to the body by introduction through an abraded surface of the skin or mucous membranes. The delicacy of the latter renders infection through them quite easy. They may go in through the intestinal tract and be absorbed by its wall. They may go in through the tonsils, larynx, or trachea. In exposure to cold with the congestion and sensitiveness of the larynx produced thereby we have an opportunity for the absorption of bacteria. Not all bacteria can enter by all ways and produce disease. The pus cocci, if swallowed, are destroyed by the gastric juice, while typhoid bacilli usually pass the stomach uninjured. Typhoid bacilli rubbed into the skin would be followed by no disease, but pus cocci so applied would cause boils. Most of the secretions and excretions, except, of course, the feces, may be said to be mildly inhibitive to bacterial growth. The defences of the body to a local introduction of bacteria depend upon the healthiness of the skin and mucous membranes. The resistance offered has been found to be due to a power supplied by the blood serum. This is discussed later. Any physical condition such as a burn or wound reducing the healthy trim of the body renders invasion easier. Injury and intoxication materially favor the activity of bacteria either previously within the individual or introduced at the time. Normal bodily resistance is impaired by excessive hunger and thirst, by exposure to cold and wet, or by prolonged muscular or mental strains.

Conditions resulting after the entrance of bacteria into the body may be defined as follows: *Infection* is best considered as the presence of disease-producing germs and the evidence of their effects. *Intoxication* is the condition due to the poisons elaborated by bacteria. *Bacteremia* is the mere presence of bacteria in the blood while *septicemia* is the circulation of bacteria and their products in the blood, with some involvement of all the organs in the body. *Pyemia* is similar to the last but includes the production of many abscesses throughout the body. Fever may be described as a disturbance by bacterial poisons of the mechanism in the brain which controls the heat of the body.

Some bacteria merely multiply in the body and exert their effect simply by their mechanical presence without any peculiar poison. Others have the power of elaborating poisons which are specific or individual and whose effect is added to that of the bacterial bodies. The latter form the larger percentage, and it is with them we shall deal chiefly. The ability of bacteria to cause disease is spoken of as their *virulence*. Each individual kind of bacterium produces only one form of disease, and always that one form. In the early history of pathological bacteriology Koch elaborated certain rules or postulates by which the relation of bacteria to disease is determined. They are essentially that the same bacterium should always be found in the same clinical disease, produce this disease when injected into animals, be recovered again from the animals, and retain its biological characters. By this means the peculiar expression of bacterial disease has

been found, and thus it becomes possible to separate those diseases which are wholly due to the bacteria themselves and those principally arising from the bacterial poisoning.

Bacterial Toxins.—Diphtheria is a disease wherein the bacteria reside and grow on a free surface, such as the pharynx; but their poisons are absorbed and carried in the blood stream, thus producing the peculiar symptoms of the disease. If, however, this toxin is taken, entirely free of diphtheria bacilli, and injected into animals, the same results can be obtained so far as the symptoms are concerned. This is likewise true of tetanus.

For the development of typhoid fever and septicemia it is necessary that the bacteria themselves should circulate in the blood stream. The reason for this is that while the poisons of the diphtheria bacilli are soluble in fluids and separable from the germs, the poisons of the typhoid bacillus, for instance, remain within the body of the germ and are only effective when the cell dies and disintegrates. The former poisons are called *extracellular* toxins and the latter *intracellular* toxins or *endotoxins*. In practice the word toxin unqualified means extracellular toxins, while intracellular poisons are specifically called endotoxins. Some bacteria (cholera for example) develop both kinds.

The local gross effects of bacterial invasion are expressed in inflammation, which is greatest in those which act by their mechanical presence in a confined locality, usually aided by some of the posions mentioned above.

Bacterial poisons, it might be said, usually express some definite predilection for special organs or tissues. For instance, the tetanus toxins attack the brain. The streptococci attack red blood cells, and the typhoid bacillus settles in the lymph glands of the small intestine.

Incubation.—After bacteria have gained their foothold there is a certain lapse of time until their effects become evident. This is the incubation time. Its length depends upon the number of organisms entering, their virulence, and the resistance of the body.

Mixed Infection.—Sometimes there is more than one kind of bacterium in an infection. This is called a mixed infection, and although there is the expression of both causes, one usually predominates. This usually results from the entrance of the second invader, owing to the lowered resistance of the body produced by the first invader.

Transmission of Disease.—The transmission of diseases from one individual to another takes place in various ways, but it may be said in general that the means of transference must present conditions favorable for the retention of virulence on the part of the bacteria. Some bacteria, notably gonococci and influenza bacilli, die very quickly when dried or exposed to direct light. On the other hand, tubercle bacilli resist drying and diffuse light for several days. Coughing and spitting transfer infective organisms from the mouth to the air, and persons in the vicinity may receive them. Clothes soiled with discharges, both urine and feces, from typhoid patients, contain the bacilli and are capable of carrying the disease.

Scales from the skin in the acute eruptive diseases of children may transmit infection. Milk and water have been known to transmit diphtheria, typhoid, scarlatina, and other conditions. Insects transmit disease in two ways, mechanically and specifically. Diseases like typhoid and tuberculosis may be transmitted by flies, which soil themselves on excreta or sputum and deposit the infective matter upon food or other objects, which later get into the human body. Other diseases probably to be credited in this category are plague and diphtheria.

In the other class of insect-born disease the transmission can only take place by this means. Thus malaria is only transmitted from the sick to the uninfected by the Anopheles mosquito, sleeping sickness only by the tsetse fly, and yellow fever only by the Stegomyia mosquito. In these insects there is a development of the virus to such a degree that it can be infective for an unprotected person, and for each disease this so-called cycle of development is necessary for its further propagation. None of the diseases demanding an insect for its spread can be transmitted by one person to another by the most intimate personal contact. It may be laid down as a law that with the exception of the few infectious disorders only carried by insects, intimate personal contact is the most prolific source of the spread of disease.

The objects before mentioned—clothing, dishes, books, utensils, and so forth—called "fomites," were formerly believed of considerable importance in transmitting disease, but latterly more weight has been laid upon individuals as carriers of viruses. This has

come to pass because it has been found that more persons contract disease after having come in contact with persons than with objects from sick-rooms, and for this reason much room and object disinfection has been stopped. The writer still thinks that disinfection of a room should be done before physical cleaning, because of the possible danger to the cleaners of such a room where the virus may lurk in corners and crevices.

Persons suffering with an infectious disease are, of course, the greatest danger in communication, but other persons may also carry infection. Attendants upon typhoid, diphtheria, or meningitis patients may carry upon the hands or clothing or in the mouth and nose, bacteria of the respective diseases without themselves having the disease, and may be called "passive" or "accidental" carriers. Doctors and nurses too often innocently are in this class. After recovery from the acute attacks of some diseases, notably *typhoid*, diphtheria, and dysentery, patients frequently carry the germs for indefinite periods; these are called "chronic carriers." Such persons are great menaces and are usually controlled by health authorities when known, but as certain diseases are endemic among us, particularly such conditions as scarlatina, for which the quarantine is very rigid, the number of so-called "hidden carriers" must be very great.

Bacteria are directly the cause of ptomain poisoning, although the ones concerned may not live within the body. Ptomain poisoning is a violent irritation of the gastro-intestinal tract by certain poisons produced from putrefaction of meat and fish by bacteria. The

foods may be little or not altered by these poisonous substances in them. They are in small quantity in the food, but are easily and quickly absorbed. It is possible that for a short time after ingestion of the meat the formation of these ptomains may continue. The ptomains are toxins, but they are formed by altering the chemical composition of the meat rather than by any peculiar products of the bacteria or poisons within their bodies. The condition is not transmissible.

IMMUNITY.

The resistance offered to the entrance of micro-organisms into the body has already been referred to, and now the method by which our physiology gets rid of the effects of these noxious agents must be considered. It is a well-known fact that illness does not occur every time pathogenic bacteria gain a foothold on or within the body. Sometimes a small number of bacteria overcome the primary defences and yield when the reserve powers have been brought into play. Again, a low grade of virulence may be possessed by the invaders, and although many enter, the specific disease process is halted by the economy. Moreover, some individuals seem to be poor hosts for certain bacteria, while others are received readily. The general resistance of the body to disease is spoken of as immunity. Immunity, as the term is usually used, means that an individual is not susceptible to a disease, but not necessarily that he would not be infected under very severe circumstances.

Types of Immunity.—Immunity is classified as (1) natural or racial or species immunity, and (2) acquired immunity, which latter has been further divided into active and passive.

Natural immunity is the condition wherein a certain disease does not occur in the type of animal under consideration, as, for example, the dog does not take typhoid fever even when fed a pure culture of the specific germs. There is also a relative natural immunity. Cats present great resistance to infection with anthrax.

Racial immunity is shown by great resistance of the negro to yellow fever.

There is also individual immunity, as shown by the passing of a person through a virulent epidemic without the slightest sign of illness.

Acquired immunity is that resistance which a person obtains by passing through an attack of disease. That a second attack of measles or scarlatina seldom occurs is well known. This is seen also in typhoid fever. Such an acquired immunity is called *active acquired immunity* because the economy has had to work for its own protection, and it is only good for the one kind of disease, supplying no protection to any other kind: that is, it is specific. There is also a passive acquired immunity, by which is meant that some protective substances from another individual are added to the natural resistance of the body. This passive acquired immunity is very well shown in diphtheria when the serum of a horse which has been rendered resistant to the toxin of the diphtheria bacilli is given to the patient. This horse is said to possess

active artificial immunity because it has been given the poisons themselves in such a manner that its blood has been able to develop anti- or against-poisons or antitoxins, strong enough to neutralize the toxins of the diphtheria bacilli. This blood is suitable to be transferred to another individual, and in the body of the latter offsets the effects of the toxin of the diphtheria bacillus. In other words, the horse's economy has worked actively against the poison, whereas the person receiving the horse's serum has not worked, but merely received a neutralizing substance from the horse's serum; it has been passive. This passive immunity is also seen in the treatment of tetanus by an antiserum (see Antitoxins), and lately Flexner has elaborated a method by which the poisons of the meningitis coccus are neutralized, here again by using the serum of horses injected with this coccus.

Artificial immunity is one that has been produced intentionally by the physician. The term may be correctly applied to any form except the natural or active acquired immunities, but it is usually reserved for the various procedures in experimental medicine whereby antiserums or vaccines are manufactured.

Anti-endotoxins.—These bodies, comparable to antitoxins, are developed in the blood serum when the system harbors bacteria whose pathogenic power depends upon intracellular poisons. Many kinds of anti-endotoxins or antibodies (a term embracing antitoxins also but more commonly used, as here) are formed. The important ones are discussed under the Actions of Bacterial Toxins and their Antibodies.

Antitoxins.—The production of antitoxins hinges on this subject. Antitoxins may be described as the substances produced in the blood or blood serum of animals injected with the poisons elaborated by bacteria, but soluble and separable from the germ cells. The toxins used to make the injections into animals are obtained by growing the bacteria in broth and then filtering off their bodies. They are distinguished from the poisons described in a preceding paragraph in that no destruction of the germs is necessary to produce these separable toxins.

Recapitulation.—To recapitulate briefly, active acquired immunity is produced by injection of living bacterial cells when incapable of producing disease, or by their endocellular poisons or extracellular separable toxins. In the case of the latter it is possible to take from the blood serum of the immune animals something which will neutralize the toxins introduced, in other words, the principle involved in making of diphtheria and tetanus antitoxin. The former, nonvirulent germs or their poisons, is used now as the basis of bacterin treatment.

Action of Bacterial Poisons and their Antibodies.—This matter is very complicated and not by any means perfectly understood by the most profound scientists. It is, moreover, unnecessary to enlarge upon it in a work of this kind, and tracing the methods as simply as possible is sufficient.

The free soluble toxins stimulate the production of antitoxins which have an attraction for the toxin, and for it only. Therefore, when any free toxin and free antitoxin come together they combine, and one neutralizes the other.

In the case of the reaction of bacterial cells or their endotoxins the result is more complicated. Many substances are formed, again called anti-, or in general, antibodies. Three will be considered: (1) The antibodies which dissolve bacterial cells; (2) those which clump them; and (3) those which encourage the white cells of the blood to eat them. The substances exist in minute quantities in normal blood.

1. *Bacteriolysins.*—The first antibodies cause a dissolving of the bacterial cells. These antibodies are called bacteriolysins (adj., bacteriolytic). There is in all blood, whether normal or subjected to immunizing procedures, a substance called complement, which makes possible these combinations of antibody and germ.

2. *Agglutinins.*—Agglutinins are substances which cause clumping of bacterial cells, but do not dissolve them. They are made use of in the diagnosis of some acute fevers, notably in the Widal reaction of typhoid (see Typhoid Fever).

3. *Opsonins.*—These are substances which act upon bacteria and prepare them for consumption by certain cells of the body, especially of the blood, called *phagocytes,* a term applied because they have the power of devouring foreign substances. Bacteria are such, and it is the task of these phagocytes to remove them. These cells are also migrating cells, as they leave the blood stream and wander over the body. It has been found that in some conditions their power of consuming bacteria is below par, and, further, that if small numbers of germs incapable of producing disease are introduced, the power of these cells may be stimulated for

the particular kind of germ introduced and not for others. The bodies producing this increased eating or phagocytosis, opsonins, are supposed not to act upon the white cells, but upon the bacteria and make them more suitable as food for the leukocytes. These phenomena have put a valuable method of treatment in the physician's hands. In subacute localized disorders particularly, but also in definitely acute and chronic troubles, injections of dead cultures of the bacteria, responsible for the condition, are made beneath the skin. The progress of treatment is followed by a long, elaborate test of permitting the leukocytes of the blood of the patient, and as a control, those of a healthy person, to feed upon the bacteria in question in test-tubes kept at body heat. If the number of germs consumed by the patient's leukocytes rises during the course of the treatment, he is considered as benefiting from the injections. His general constitutional condition is closely watched also. It is now attempted to use for "vaccination" a culture made from the patient's disease, the so-called "autogenous vaccine."

Principles of Vaccine Treatment.—To return for a space to active immunity, it is well to consider here the basis of the present-day bacterin treatment. The ordinary vaccination against smallpox depends upon the fact that human smallpox virus passed through a calf for a number of times loses its power to produce smallpox in man. It does retain power to produce a sore, and this sore contains sufficient of the poison related to smallpox virus to stimulate in the vaccinated person a condition resistant to the virus which would

cause true general smallpox. The great Pasteur found that if he heated anthrax bacilli and injected them into sheep, these animals became resistant to the disease anthrax. Since the time of Pasteur the management of the process which has been called "active immunization" has been learned. To accomplish this a virus must be treated as was the virus of smallpox, that is, it must be rendered incapable of causing general disease, but it must not be so altered that it has no relation to its original form. The living organisms can be taken and subjected to higher or lower temperatures than those preferred by the individual species, or they may be injected into animals until they will merely live without producing disease. This is called reducing virulence. They may be killed by heat or obtained in mass and crushed and ground into a pulp. Again, the broth or other material upon which they grow may be used after removing the bacterial bodies by filtering them off through porcelain filters. Having obtained the virus in a reduced state either dead or as active principles, it is injected beneath the skin of the individuals whom it is desired to protect, beginning in minute doses and increasing the quantity as the condition permits. By this means the resistance of the animal or person to this particular germ is increased, and the process corresponds to that of the production of antitoxin in horses, that is, making an antipoison, or, as it is called, an antibody. The method just described is usually reserved for the bacteria which produce intracellular or endotoxins. The method has been used in treating anthrax, typhoid, cholera, etc.

Serum Treatment.—Since it is possible to create in animals by the injection of bacteria, a condition of the blood serum which neutralizes the bacterial poisons, there has arisen a specific treatment of many bacterial diseases. The ones found most suitable for this therapy are diphtheria, tetanus, meningitis, dysentery, cholera, streptococcus, and pneumonia. The antiserums are administered by injection under the skin of patients, and serve the purposes first of neutralizing any poison which may be circulating, of agglutinating free germs, of stimulating the phagocytes to devour the organisms, and of keeping the poisons from destroying the cells of the organs. The various antisera will be discussed under their respective diseases.

Anaphylaxis.—When the principal constituent of flesh and blood, protein, is taken into the alimentary tract it is digested and absorbed because digestive ferments are there for the purpose. If it be injected in solution under the skin a ferment has to be prepared in order to remove it. If, now, it be injected a second time this ferment is ready and attacks the protein, digesting it rapidly. The products of this digestion appearing suddenly in the tissues are apt to poison them. If a guinea-pig be injected with horse serum and the dose be repeated ten days later, the animal will have dyspnea, skin irritability, and die. This is *anaphylaxis,* which we shall for our purpose consider as a hypersusceptibility to protein matter not taken in the normal manner. Some persons exhibit great susceptibility to antiserum injection because they are anaphylactic to the horse serum, and while a few deaths have occurred, they usually react by the

appearance of "serum sickness." This is a condition appearing five to twelve days after serum injection, consisting of skin rashes, malaise, fever, and albumin in the urine. The reaction occurs most often in persons who have asthma when in the presence of horses, and the physician should inform himself as to this contingency. No reaction will appear if the serum be given very slowly, or the first dose divided by a few hours, or if a second injection be given in two to four days. A single large, rapid injection of horse serum should never be given to a patient, because it might make him susceptible to horses or to later serum injections, against which a second dose within five days will protect him. Nurses should have a hypodermic of $\frac{1}{150}$ gr. of atropin ready for emergencies, since this drug is the only treatment for acute symptoms after antitoxin injections.

The reader must not picture that these so-called antibodies are substances that can be handled. They are invisible chemical parts of the serum of the blood, and only perceptible through extremely delicate laboratory procedures. The present conception of their action was worked out by Dr. Ehrlich, a German chemist and physicist. His theory, broadly speaking, assumes a group of substances circulating in the blood which can be stimulated to meet and destroy invaders, and thereby protect the body. Besides the three methods above outlined, in which practical therapeutic use has been made of the known facts in the study of immunity, still others have been devised, but they are scarcely yet out of their experimental stage.

CHAPTER VII.

PREPARATIONS FOR AND PROCURING OF SPECIMENS FOR BACTERIOLOGICAL EXAMINATION.

WHILE it may not be the duty of the nurse to obtain all specimens for bacteriological purposes, she is often requested to obtain the more common things, and it behooves her to know how this should be done.

The nurse is very commonly expected to prepare the patient for technic used by the physician in procuring specimens, and she should know the more important parts of such technic.

Collection of Pus.—For the taking of cultures of pus from abscesses or from infected surfaces of ulcers or sinuses, an applicator, usually of wood, wound with cotton and sterilized within a glass test-tube, is used. The nurse most commonly sees this in connection with throat cultures. When this applicator is passed over the diseased surface, some of the bacteria present adhere to the cotton. The adhering particles are transferred by the physician to some suitable food upon which the germs will grow. In preparing an exposed infected surface for culture-taking, the nurse need have ready only sterile water or a very weak (1 per cent.) boric acid or sterile physiological salt solution. Anything stronger may destroy the bacteria.

Collection of Sputum.—Sputum to be examined for the tubercle bacillus should be received in a thoroughly

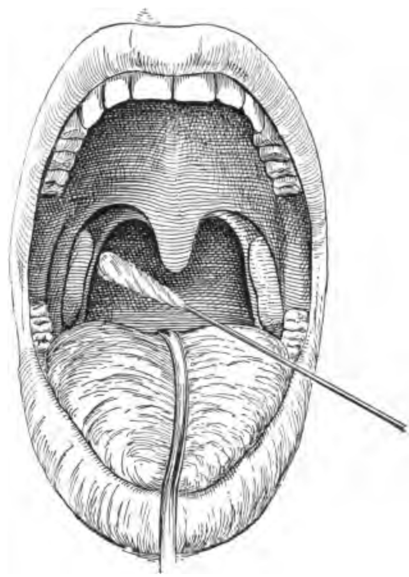


Fig. 22.—Showing the method of taking a culture from the pharynx. (Morrow.)

Fig. 23.—Wide-mouthed bottle for collecting sputum.

cleansed and dried wide-mouthed bottle. This is given to the patient that he may expectorate directly into it. When the specimen has been collected by the

patient, the bottle, including the inside of the mouth, should be wiped off with a cloth moistened with 5 per cent. carbolic acid solution. When specimens of sputum are intended for careful bacteriological cultivation with the idea of finding out what the causative bacteria in the case may be, the procedure is different. In this case the bottle, again a wide-mouthed one, must be plugged with raw cotton and sterilized, preferably by dry heat. Someone should supervise the collection of the specimen and see that the patient spits a representative (instruction from doctor) sample directly into the bottle and does not let it touch the outside of the neck. The part of the cotton plug which extends beyond the mouth of the bottle should be held by someone and the stopper part not allowed to touch anything while out of the bottle. After the plug is replaced the outside of the bottle is cleansed, as for tuberculosis sputum.

The sputum is an excretion from the trachea, bronchi, and lungs, and care should be taken that the specimen collected is such and not saliva mixed with posterior nasal mucus. In children it is necessary to induce a cough and to collect the sputum on cotton-tipped applicators.

Collection of Urine.—The collection of urine for bacteriological purposes must be done by catheterization, using all possible surgical precautions as to genitalia, hands, and instruments. The urine must be allowed to fall from the end of the catheter directly into a bottle or test-tube sterilized with a raw cotton plug, the plug being removed when the collection is ready and held carefully, so that the part which fits into

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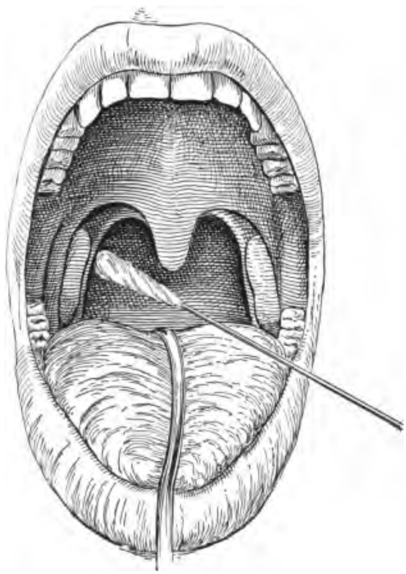

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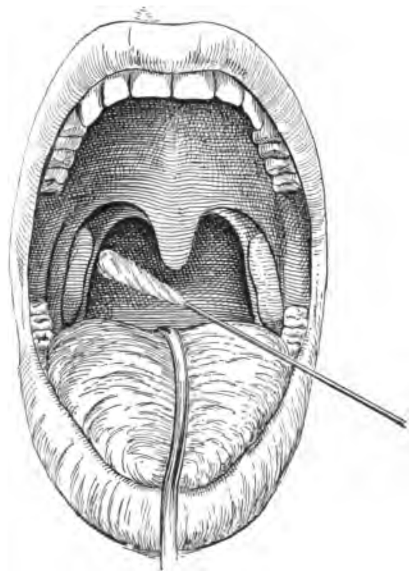

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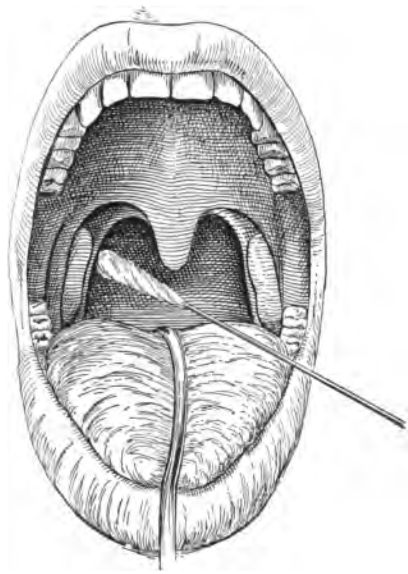

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the tube touches nothing. This is best held by an assistant during catheterization, so that it will not be contaminated.

Collection of Feces.—The best method of collecting feces is to have them passed directly into a sterilized Mason jar. This, however, is not always practicable, and they may be received in a thoroughly cleansed bed-pan or chamber and transferred afterward to the Mason jar by pouring or by a pair of forceps sterilized

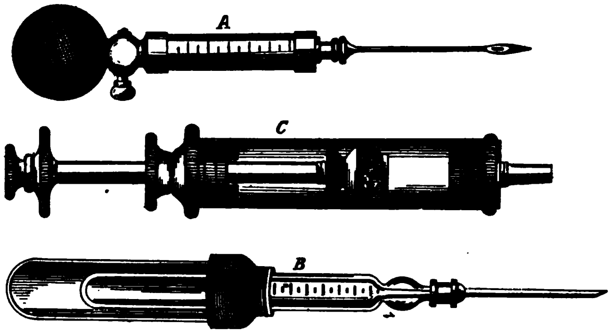


Fig. 24.—Forms of hypodermic syringe: *A*, Koch's syringe; *B*, syringe of Strohschein; *C*, Overlack's form.

by passing through a flame. The cleansing of the receptacle should be done by soap and water, alcohol, and sterile water.

Collection of Blood for Widal Test.—In preparing for a Widal blood test (see Typhoid Fever) the finger or ear lobe is cleansed with soap and water and alcohol. It is then pricked with a needle and the blood collected on unglazed paper, glass slides, or in glass tubes. For direct examination of the blood the procedure with the patient is the same.

Technic of Punctures.—Perhaps the most important bacteriological technic with which the nurse has an important duty is the puncturing of cavities such as drawing fluid from a chest or knee, the cerebrospinal fluid from the spinal canal, or the taking of blood from a vein. For all these the skin over the site of operation is cleansed precisely as for a major operation. It is the practice of the author for vein puncture, in making a blood culture, to have the arm at the bend of the elbow inside (sometimes the leg is used) scrubbed with soap and water, using a very soft brush, washed with sterile water, and either painted with 10 per cent. iodin alcohol or a wet dressing of 1 per cent. formaldehyde applied; if the puncture is not done for some time, fresh iodin solution is used when everything is ready. These two methods have been found very successful in destroying the bacteria always present in the deeper layers of the epidermis. They are chiefly small white cocci not unlike the cocci that cause abscesses. They will be considered later under the name *Staphylococcus epidermidis albus*.

There is little to be done by the nurse aside from preparation and general assistance, but she should know what is being done and why.

Fluids are removed from the pleural cavity or spinal canal and elsewhere, because in these locations bacteria of specific kind or in characteristic conditions are to be found. For instance, in cerebrospinal meningitis the causative germs are found within the pus cells of the cerebrospinal fluid, as double, biscuit-shaped cocci, and they have a particular staining reaction by which they are recognized (see Chapter VIII.)

The blood is taken from the veins and grown in broth alone or broth stiffened with gelatin or agar-agar in order to find out if living bacteria are circulating in the blood stream, as is the case in typhoid fever and septicemia.

For entering these cavities or veins a syringe, preferably of glass, with a good-sized needle, larger than the medicinal hypodermic type, is used. The syringe and needle may be sterilized by boiling, with a pinch of soda, for ten minutes or by autoclave, the best means provided the operation be done immediately. Metal parts will rust if the syringe and needle are sterilized by moist heat and allowed to dry out. The hot-air oven is not suitable for sterilizing in this case.

Milk.—Nurses are frequently required to send samples of milk for examination, especially in well-directed hospitals. Of course, when bottled milk is used an unopened quart bottle should be sent to the laboratory. When the milk is supplied in cans it is necessary to have a sterilized 50 c.c. pipette and a sterilized bottle or flask. The lid of the can is carefully removed, the pipette, held only by the mouth end and protected throughout its length from touching the neck of the can, is plunged into the milk for six inches and filled by suction with the mouth. The milk is transferred to the sterile bottle or flask, again observing the precaution of not touching the neck of this container. The stopper or plug of the receiving vessel is best held by an assistant and the part which fits into the vessel must touch nothing. As soon as the milk is collected it should be put on ice or sent to the laboratory immediately.

CHAPTER VIII.

THE ACUTE CHIEFLY LOCALIZED INFECTIONS OF PUS NATURE—THE PATHOGENIC COCCI.

So far the general conditions under which bacteria live, grow, and exert their peculiar forces have been considered, but now a more direct study will be undertaken of individual groups and single species, with the object of learning what the various diseases due to microörganisms are, and what relations the germs bear to the clinical disease.

Perhaps the most frequent condition a nurse has to meet is an abscess or local surgical infection with or without pus. All the technic of hospital work hinges on the fact that organisms capable of producing pus are ubiquitous, so that the protection of wounds or of patients of medical cases with their lowered vital resistance is imperative. There is no one germ that always produces local infection or pus, but many bacteria possess this power. Moreover, some bacteria may produce a simple abscess in one case and a violent inflammation of the heart lining in another. This depends in part upon the virulence of the germ and also upon its mode of entry. If pus cocci fall upon a simple cut in the skin of an otherwise healthy person, a red, dropsical swelling or an abscess may result.

Again, if they fall upon a wound made for an abdominal operation, they may penetrate to the interior and cause a peritonitis. Still, again, pus germs may make their entrance in the ways first cited, but cause no trouble at the site of entrance, being carried hence by the blood stream to cause trouble at other places. Any reaction set up by bacteria is called inflammation, and in no other conditions is this so well illustrated as in the effects of "pus cocci."

Inflammation.—Inflammation is the reaction on the part of the body to the presence of bacteria themselves or to their products. It is expressed by swelling, increased heat, redness, pain, and some loss of function. It is not worth while to go deeply into what may be seen under the microscope in inflammation, but to explain the physical expressions of inflammation just given a few lines seems advisable. The swelling, heat, and redness are due to an increase of the blood in the affected part, called forth by forces exerted by the bacteria. These are protective phenomena whereby the body sends an excess of its most potent protective tissue, the blood, to stop the onslaught of microörganisms. The forces exerted by the invaders attract the white cells of the blood, which collect about the outsiders and try to destroy them. The pain is due to the irritation of the fine nerves of the part, and loss of function can be explained by a combination of all the other features of inflammation. The further course of this reaction depends upon which force is the stronger, the body defence or the bacterial attack. If the former exceed the latter the part assumes its normal character after a brief time. As the infecting forces become greater

in relation to the defence, just so there are greater effects in the production of infection. In increasing severity there are the following grades:

Abscess is a local collection of pus in which the resistance put up by the tissue prevents the inflamma-

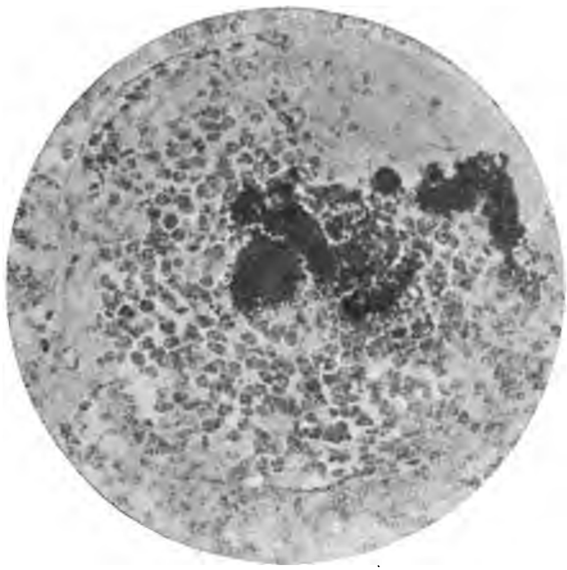


FIG. 25.—Secondary infection of a glomerulus of kidney by the Staphylococcus aureus in a case of ulcerative endocarditis. The cocci (stained doubly) are seen plugging the capillaries and also lying free. × 300. (Muir and Ritchie.)

tion from spreading, thus keeping it in a limited space. There is some effect on the general body by absorption of a few bacteria or their poisons, but a densely packed zone of leukocytes around the pus keeps it from general invasion. Should this barrier be broken or the resistance be too low to hold the invaders a spread of

the pus occurs and *cellulitis* or *phlegmon* arises. The next grade of severity would be *septicemia* or *pyemia*, defined before, which arises when the active inflammation enters and involves the bloodvessels. The softening of tissue into pus is called suppuration, which may be defined as the destruction of tissues and cells by bacteria and their products. Pus under the microscope is composed of white blood cells, particularly the so-called polynuclear leukocytes, microörganisms, some of which are free, others englobed by phagocytes, partly or wholly destroyed tissue, and, at least early in inflammation, a delicate meshwork of coagulum called fibrin; the last is dissolved shortly as the suppuration proceeds. There is also some granular fluid.

The fluid and cells which appear in inflammation are collectively called an exudate. This may be of several forms; it may be true pus; it may be a thin, watery fluid in which are floating shreds of a gray, friable character, called lymph, in reality a coagulum, such as is formed in blood clotting, but without red-blood cells; it may be a tenacious covering of a surface, called a false membrane, such as is seen on a diphtheritic throat, more or less closely adherent to the surface from which it arises; it may possess special characters, such as hemorrhagic when much blood is admixed, or mucoid when it resembles mucus.

PUS-PRODUCING MICROÖRGANISMS.

It has been stated that there is no particular germ always responsible for pus, but some varieties of the round bacteria are the commonest causes. They are

called micrococci or staphylococci, and streptococci. Certain members of the group of cocci may also do other things than produce simple pus or abscesses. These will be considered at the end of this chapter. Bacteria other than cocci which can produce pus are the colon bacillus, pyocyaneus bacillus, typhoid bacillus.

Staphylococcus Pyogenes Aureus.—Of the micrococci there is one particular species of importance which by some bacteriologists has been divided into two

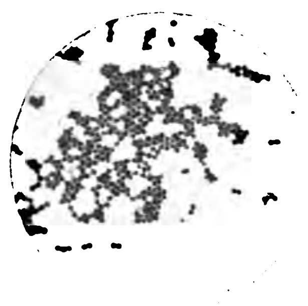


FIG. 26.—Staphylococcus. × 1100 diameters. (Park.)

varieties because members of the group differ in their ability to produce color in laboratory cultures and because the one having a golden-yellow pigment is somewhat more frequently found in pus. This color-producing organism is called the *Staphylococcus pyogenes aureus* (the golden pus-producing coccus). See Plate II for an idea of growth and color. It is about $\frac{1}{25000}$ of an inch across and appears under the microscope as single individuals, pairs, but more frequently in grape-like groups. It stains fairly well with most

dyes used. It does not form spores and does not move from place to place by its own power. It grows best about 85° F. It is killed about 56° C. or 130° F. at ten minutes in the moist condition, but when completely dry it may require boiling to kill. When dried on cloth or paper it may live three months. This organism grows well on ordinary laboratory foodstuffs, and produces, particularly in the presence of diffuse light and oxygen, a golden yellow color. This coccus has the property of coagulating milk and liquefying gelatin by the ferments it produces. It is killed by corrosive sublimate, 1 to 1000, in ten minutes in watery solution. In pus a considerably longer time is required. 1 to 20 carbolic kills in one minute; 1 to 500 in about one-half hour. The pus in which the staphylococcus lives supplies a protective envelope, and should be well mixed and diluted with the germicide.

This organism is very virulent for the smaller animals, which may be infected by rubbing on, or injection under, the skin. It will then produce a local abscess or septicemia. It may produce acute inflammation of the interior of the heart, or bone disease.

Staphylococcus Pyogenes Albus.—The *Staphylococcus pyogenes albus* is precisely like the foregoing except that it does not produce the golden-yellow pigment, but grows in a porcelain-white manner. There is an organism on the skin to which we give the same name, but add the word "epidermidis." It is constantly present on the surface, in the epidermis, and in the glands of the skin. Since its pus-forming ability is so feeble, "pyogenes" may be omitted and the

name *Staphylococcus epidermidis albus* given. It does not produce disease, but is of constant annoyance in making blood cultures. Another staphylococcus produces a lemon-yellow color.

These staphylococci are very widely distributed and seem to be almost constantly upon the surfaces of the body, upon skin, in the sebaceous and sweat gland openings, on the mucous membranes. For this reason they are of great surgical importance and may originate, in a postoperative infection, from the patient, physician, or nurse. Their rather high resistance to disinfection demands great care in surgical technic. The commonest conditions in which these cocci are implicated are pimples, boils, carbuncles, lymph-gland swellings, osteomyelitis and endocarditis.

Vaccines and Opsonins.—The use of killed bacteria to produce an increased resistance against an existing infection has already been discussed. This method of treatment is particularly suitable for infections with staphylococci. The procedure is about as follows: Cultures are made from the diseased part, grown in large quantities on laboratory media, washed off, suspended in physiological salt solution and heated to a temperature which will kill their disease-producing properties and stop their multiplication, but will not alter their peculiar chemical composition. The number of bacteria are then counted by a special technic and hypodermic injections are made of definite numbers. The size of dose and rate of increase of number injected are controlled by what is called the opsonic index. The opsonins, as will be remembered, are substances in the blood which make the bacteria suitable for ingestion by

the white cells of the blood or phagocytes. The opsonic index is the relation of the ability of the patient's white cells to ingest bacteria as compared with a normal person's white cells. This latter is considered 1. If a person is infected with the pus cocci it means that his opsonic index is below 1, and we try to increase it up to or beyond 1. Many different conditions have been found amenable to this treatment, but furunculosis has responded better than others.

Streptococcus Pyogenes.—The cocci which grow in chains, streptococci, must now be considered. There are many varieties, but the *Streptococcus pyogenes* (the pus-producing streptococcus) is the only one that need be considered. This organism gives rise chiefly to the spreading inflammation, such as erysipelas, cellulitis, and septicemia. It *may* cause a localized abscess. It is a rapidly growing organism when conditions are suitable, and is the commonest cause of puerperal infection. It frequently attacks the blood and causes a solution of the red cells. Streptococcus peritonitis is usually fatal. It is commonly present in the mouth, and may produce tonsillitis. It is not so wide-spread in its distribution as the foregoing coccus, but is greatly feared in surgical and maternity wards. Streptococci are capable of producing inflammation of many sorts and no tissue of the body seems able to resist them when of sufficient virulence. They most commonly affect the tonsil, heart lining, lung and subcutaneous tissue. Disinfection of materials from streptococcic infections should be done by carbolic acid, bichloride, or hydrogen peroxide. Great care is necessary in the handling of dressings,

clothing, and utensils from patients with streptococcus infections, because, despite the low resistance of the organism, transmissions take place quite easily, and it is highly probable that it always occurs by direct transference of the germs as they live a very short time exposed to light and air. This is particularly true of puerperal infections, which are commonly the result of infection with bacteria of high virulence. This germ, unlike the staphylococcus, cannot infect through the undamaged skin, demanding a wound for its entrance. Streptococci vary in virulence and

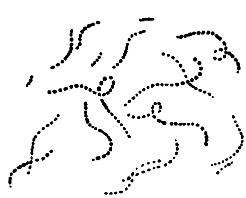


FIG. 27.—Streptococcus pyogenes. (Abbott.)

when the particular family of germs happens to be very virulent, a single coccus may transmit an infection.

In diagnosticating streptococcic infections it is necessary to make smears on glass slides and cultures in appropriate media. The germs are found to be very small single cocci varying from $\frac{1}{50000}$ to $\frac{1}{25000}$ of an inch, dividing only in one plane and therefore growing in chains. They are unable to move of themselves, stain well by most methods, multiply best at 37° C. (98° F.), but also at lower temperatures, and grow as very delicate gray colonies. They have no effect upon

milk or gelatin. On media containing blood they have the property of dissolving the red coloring matter.

They are killed in ten minutes when exposed to 52° C. (126° F.). When dried in blood or pus they may live for a considerable time at room temperature, but die quickly at body heat unless their food is repeatedly renewed. They are killed by corrosive sublimate, 1 to 1000; carbolic acid, 1 to 100; and hydrogen peroxide, 1 to 100, in ten minutes if exposed in water. Pus supplies a protective envelope, and the germicide must be allowed to act longer. Streptococci are very virulent for most lower animals and the same lesions may be produced by artificial injection as arise spontaneously in man. Streptococci produce a slight amount of extracellular poison, but more arises from the disintegration of the bacterial cells. The vaccine treatment is not always successful.

An antistreptococcus serum has been prepared by injecting horses with a number of cultures in order to call forth antibodies to all varieties. In all cases of severe streptococcus infection this should be used and good results have been reported from some quarters.

To diagnosticate infections by the staphylococcus or streptococcus we are obliged to make our technic suit the individual case. If an abscess exist it is sufficient to collect the pus. If a cellulitis or bone disease is to be examined, it is necessary to go deeply into the tissue and select the bloody material near the healthier tissue. In septicemia or heart disease, a blood culture is made. Both organisms grow with ease upon ordinary culture media.

MICROCOCCUS GONORRHEA.

Gonorrhea is an acute inflammatory and pus-forming disease with its chief manifestations in the mucous membrane of the urethra. It is caused by the *Micrococcus gonorrhea* or gonococcus, which enters the mucous membrane directly wherever there is a slight, even invisible, abrasion. This disease is one of the venereal affections, and is probably one of the most prevalent of all diseases. In the male its acute stage lasts for three to six weeks, while in the female it may be transient or pursue a very long course. In both sexes it tends to infect the other genital organs, and is probably the chief cause of salpingitis and oöphoritis. In later stages when all bacteria have not been removed by a perfect cure, the germs penetrate to the deep parts of the mucous membrane of the external urinary channel, and there rest for long periods apparently undestroyed by the protective forces of the body, and without setting up any change by which their presence can be detected. They may be stimulated to renewed activity by a congestion of the part by any means. This peculiarity of hiding is the reason for the fact that a person once affected by this disease remains infective for others for a very long time. The bacteria reside in the Bartholin's glands of the female or the posterior urethra, Cowper's and prostatic glands of the male. At present there is no perfectly reliable method by which to ascertain the freedom from gonococci of a person once affected. Late results of this disease are urethral stricture, chronic inflammation of any other genitals, such as salpingo-oöphoritis, requir-

ing operative removal of the affected parts. Either during its acute or chronic stage, the latter more commonly, the gonococci may enter the blood stream and affect tissues other than the genitals, for which it has a predilection, the serous surfaces, joints, heart lining, or meninges. These conditions arising after such spreading are very difficult to treat, and not infrequently leave a permanent defect.

The inflammations of the eyes, notably the conjunctiva, produced by the gonococcus are very common, and one authority says that half the world's blindness is due to it. This complication is due to carrying of germs from the seat of primary disease, on the fingers, handkerchiefs, and the like, to the eye. The result is a frightful acute, pussy conjunctivitis, running a long, acute course and leaving opacities of the cornea or adhesions of the iris in many cases. Destruction of the eye may result. Not only does this disease affect those with gonorrhea, but it may be transferred to others by objects soiled with pus. The commonest transmission of gonorrheal ophthalmia, as it is called, is to the newborn. This is ophthalmia neonatorum. It is a common practice of obstetricians, especially in hospitals, to instil a few drops of a weak nitrate of silver solution (2 per cent.) into the eyes of newborns, whether there is or is not a history of gonorrhea in the mother.

A more serious and baffling phase of gonorrhea is seen in the vulvovaginitis of little girls, which frequently sweeps like wildfire through a hospital ward, despite all attempts to stay its progress. It also appears in any institution where children are in close

contact, schools, for example. It is supposed to be transmitted by water-closet seats and directly from child to child. It may be spread by bedclothes, towels, clothing, basins, bed-pans, and in other ways. Children have been known to contract the affection by occupying the same bed as an infected person. Efforts to eradicate this vulvovaginitis should be directed toward removing the source. This is sometimes impossible, since it cannot always be found. It is much better to institute a strict quarantine of every little girl admitted to a ward by using separate bed and body clothing and utensils. She should be examined by the house physician upon admission, and if necessary, proper bacteriological examinations made. If affected, such objects that are used on her as can be burned should be so disposed of. Others should be soaked in carbolic acid solution for at least twenty-four hours. It is the practice in many places to place on all female children a T-binder, which is burned upon removal. Patients must not be allowed to go to the water-closet, but a bed-pan used, to be later disinfected by appropriate solutions. Flaming objects, such as a bed-pan, is an excellent method of disinfection. The curious part about the transmission of vulvovaginitis is that its causative agent, presumably always the gonococcus, is either in a highly resistant state, or it is protected in some manner, since agencies, such as drying, that will kill the bacterium under ordinary conditions seem to have little or no effect upon it.

The gonococcus was first described by Neisser in 1879. It is classified, and correctly, among the round organisms or cocci, although it is usually seen in pairs

like two kidney beans with their concave sides together. They are also said to be of biscuit shape. Each bean is about $\frac{1}{30000}$ of an inch wide and $\frac{1}{20000}$ of an inch long. In pus or culture they are of this figure, but in the former they are characteristically lying within the pus cells between the wall and the nucleus, but not within the latter. Free pairs are also seen, but it is unwise to name them when not in the cells, because other cocci may resemble them. There is a resem-

FIG. 28.—Pus of gonorrhea, showing diplococci in the bodies of the pus cells. (Abbott.)

blance between these organisms and those of meningitis (p. 100), but the clinical differentiation is not difficult, since the diseases are easily separated.

The gonococcus does not stain by Gram's method, a quite important criterion for the bacteriologist. It is cultivated with difficulty. For purposes of growing it in the laboratory a broth or jelly must be used to which has been added some blood or blood serum or fluid from a hydrocele or the peritoneum. It grows best in the presence of free oxygen, a curious fact,

since it will live for long periods in places where there is no free oxygen. It grows best at 98° F. (37.5° C.) but dies out very rapidly. In the ice-chest it may live somewhat longer.

Direct sunlight kills the gonococcus almost at once. 105° F. (41° C.) will kill the organism in a few minutes. Almost any good disinfectant will kill it in five minutes if directly applied to the bare germ. "If completely dried, however, and protected from light, it may live on sheets and clothing, from eighteen to twenty-four hours."

This bacterium produces an intracellular or endotoxin, which is as potent when injected into animals as a devitalized mass as the living form itself, although the gonococcus has very little effect upon laboratory experimental animals. Some observers have been able, by injecting goats with coccus poison or the germs themselves, to produce an antiserum against the gonococcus, and therewith treat human cases with some success. Vaccination with killed gonococci has been found of some value in chronic stages and, by some observers, in acute stages also.

The bacteriological diagnosis is easily made by spreading some of the pus upon glass slides, staining appropriately, and examining under the microscope. In the chronic gonococcus infection the discovery of the germ is extremely difficult. For the diagnosis of obscure cases of vulvovaginitis Dr. Norris recommends a washing with 1 to 5000 bichloride solution in a pipette filled with a bulb. The chemical removes the surface epithelium and cocci hidden in the depths are drawn out. The fluid can be centrifugalized and the sediment stained.

MICROCOCCUS INTRACELLULARIS MENINGITIDIS.

Meningitis, or inflammation of the membranes covering the brain and spinal cord, may be caused by several bacteria, such as streptococci, pneumococci, and influenza bacilli, but we shall deal chiefly with epidemic cerebrospinal meningitis or spotted fever. (The latter is a common term which should be discarded for meningitis, and confined to typhus or jail fever.) Epidemic cerebrospinal meningitis is an acute primary inflammation due to a coccus called the *Micrococcus* or *Diplococcus intracellularis meningitidis* of Weichselbaum or the meningitis coccus or meningococcus. The organism probably gains access to the meninges by way of the nose, whence it passes through the sieve-like bones through which the olfactory nerves emerge from the skull. By this route it penetrates to the under surface of the brain and extends along the meninges.

The other agents of meningitis, the pneumococcus for instance, usually gain entrance by way of the blood or lymph, directly through the skull-base or by an extension from the middle ear, where suppuration may burrow through the bone.

The meningitis coccus is found in the nose and throat of patients, and also in the nose and throat of about 10 per cent. of their attendants.

The affection produces a thick, stringy, purulent exudate in the spaces between the nervous system and their coverings, the meninges, called the arachnoid space. This exudate covers the brain and cord, and fluid accompanying it distends the various cavities of

the spinal column and interior of the brain. The disease has a high mortality. It affects chiefly the young. Its results or sequelæ consist in blindness, deafness, and paralyses of various kinds. Mentality may be affected.

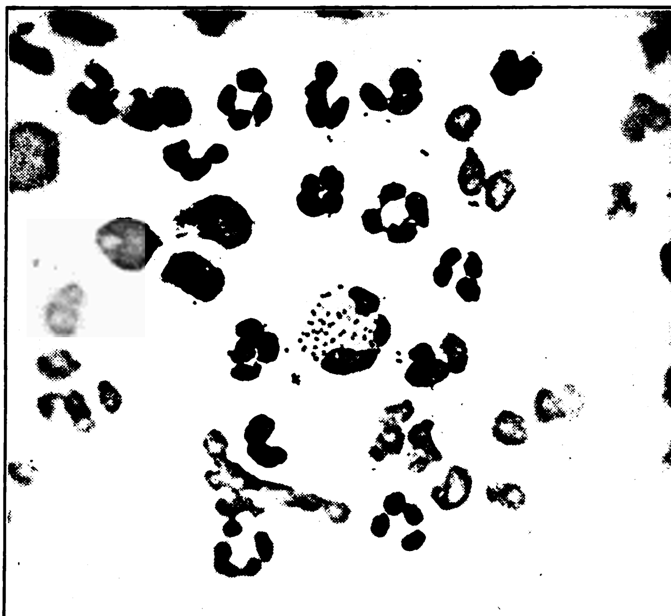


FIG. 29.—Meningococcus in spinal fluid. (Hiss and Zinsser.)

In taking care of meningitis patients the chief concern is with discharges from the nose and mouth. These cavities should be cleansed with a mild antiseptic, say boric acid, and the cotton or what not used should be burned or soaked in carbolic acid solution. The nose and throat of those in attendance should be

sprayed with an antiseptic, those containing thymol being excellent for the purpose. After death the body should be encased in a cloth wetted with carbolic acid solution.

In the diagnosis of this disease from a bacteriological standpoint, the most important procedure is the lumbar puncture. This is the introduction of a needle into the meningeal space by entering between the vertebræ of the lumbar region. Its purpose is the withdrawal of fluid. This fluid is usually thin, turbid pus containing flakes of fibrin. The turbidity is due to great numbers of pus cells. These cells contain the cocci of meningitis, which are of the same general size, shape, and arrangement as the gonococcus. They are so like this coccus that one must be well versed indeed to differentiate between the two without a knowledge of the source of the specimen. The meningitis cocci show a great variance in size and shape within the same specimen, conditions not common with the gonococci. They also stain differently, although both are decolorized in the Gram method. As is the case with gonococcus, they lie within the protoplasm, but not in the nucleus. Given a turbid fluid from a case suggestive of meningitis, it is possible to make a diagnosis by finding these cocci. The cocci may also be found in the blood. They develop agglutinins whereby an additional assistance in diagnosis may be given.

The cocci are grown with moderate ease on laboratory media, especially if they contain blood serum or glucose. They grow best in the presence of oxygen, at 37.5° C. or 98° F., but die rapidly if not put on fresh food frequently.

PLATE III

Diplococcus Pneumoniæ in Blood of Rabbit. (Abbott.)

Showing encapsulated cocci, red and white blood cells.

They are killed by heating to 50° C. or 122° F. for ten minutes, by exposure to sunlight at once, and by almost all disinfectants in appropriate strength in five minutes.

It has been possible to produce a very effective antiserum by injecting into horses suspensions of whole and disintegrated meningitis cocci. The antiserum is introduced into the space between the cord and the meninges by lumbar puncture, first withdrawing some of the spinal fluid to make room for it. By this treatment, especially when instituted early in the disease, a great deduction in the mortality, and in the deformities so frequently following meningitis, has been effected.

DIPLOCOCCUS (STREPTOCOCCUS) PNEUMONIÆ.

Pneumonia or inflammation of the lungs may be caused by a great many organisms, but by far the commonest one is the *Diplococcus* or *Streptococcus pneumoniæ* or pneumococcus. This omnipresent organism gains entrance to the body almost exclusively by the nose or mouth. It enters the air passages and penetrates to the finer parts of the lungs, there setting up a rather characteristic inflammation. In certain types of pneumonia the disease may involve whole lobes; again, small patches here and there may be involved, the intervening tissue being practically normal. From the lungs the bacteria naturally penetrate into the blood stream. This emphasizes the fact that while pneumonia expresses itself chiefly in the lungs, it is in reality a general infection. It should,

moreover, be included among the transmissible infections because it appears in epidemics, and definite instances of communication directly from the sick to the well are known.

By reason of the spread of pneumococci through the blood, complications in the form of involvement of nearly every tissue in the body may result. The interior of the heart, the pleura, and the meninges are most commonly affected. These organisms may also cause conjunctivitis, tonsillitis, otitis, and arthritis.

For diagnosis bacteriologically, cultures are made from the sputum, selecting the blood-streaked specimens, and of the blood. Sputum should be disinfected by receiving it directly in 5 per cent. carbolic solution. Not only must care be used to collect sputum, but the lips and checks of the patient should be kept clean, and all attendants should rinse their nose and throat frequently with hydrogen peroxide or Dobell's solution. Pneumococci do not live long on objects, but may be transferred by persons in the hair and nasopharynx, in which places the germs are protected from light and drying. After pneumonia it is not common for patients to remain as carriers, but attendants may be accidental carriers.

The coccus belongs properly to the streptococci, since it divides only in one plane, and its cultures may appear in chains. It has the peculiarities of growing in an oval shape in pairs, with the distal ends pointed (lance-shape), and being surrounded by a capsule. This shape and envelope are quite characteristic, and almost determinative. The coccus grows very slightly on ordinary culture media, but best when blood or

blood coloring matter is added. It then produces a faint green color and grows best at 37° C. or 98° F., but

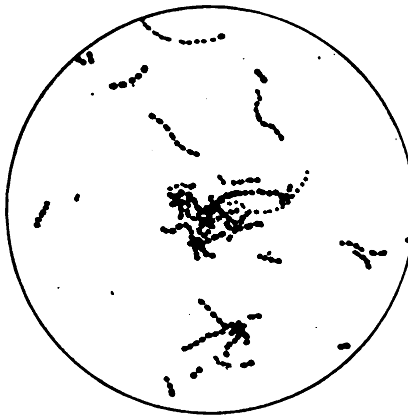


FIG. 30.—Pneumococcus from bouillon culture, resembling streptococcus. (Park.)

FIG. 31.—Pneumococci in peritoneal pus. Stained with fuchsin. × 1000 diameters. Clear spaces indicate capsules. (Park.)

does not live long, requiring repeated transference to fresh food. In sputum the pneumococcus may remain

alive and capable of producing disease for several months if protected from light. If the sputum be dried and powdered, so that it could be inhaled, the cocci live for a few days in diffused light. Direct sunlight kills them almost immediately. They are killed at 52° C. or 126° F. in ten minutes. It is said that the best way to disinfect sputum is by the addition of about one-third alcohol. The pneumococcus itself has a very low resistance to any of the ordinary disinfectants, being killed in a few minutes.

Most of the lower animals, particularly mice and rabbits, but not birds, are susceptible to the pneumococcus. However, a true pneumonia as seen in man has not been produced artificially. The pneumococcus produces a small quantity of poison aside from itself, but acts chiefly by reason of substances within the germ cell. It has been found that there are four closely related varieties of pneumococci capable of causing pneumonia and that against two of them it is possible to produce in horses a powerful antiserum. In a given case of pneumonia the causative strain of cocci is isolated and studied; if it belong to one of the two proper varieties the respective antiserum may be injected under the skin or into a vein. The death-rate of pneumonia for these two kinds has been somewhat reduced by this treatment. The use of vaccines has not been followed by uniformly favorable results. The blood in pneumonia contains some agglutinins, but they are not of much value in diagnosis

CHAPTER IX.

THE ACUTE SELF-LIMITED INFECTIONS.

In this chapter are included the infectious diseases which are due to a specific microörganism and which tend to run a definite course.

BACTERIUM DIPHTHERIÆ.

Diphtheria is a disease caused by the *Bacterium diphtheriæ*, or diphtheria bacillus, or Klebs-Löffler bacillus, characterized by the development of a so-called false membrane upon a mucous membrane or abraded surface, from which the soluble poisons are absorbed by the circulation. This false membrane is an inflammatory exudate thrown out by the body under the stimulus of the bacteria, as a means of protection against them. Myriads of bacteria are included in the meshes of this exudate. If the false membrane be removed a raw, bleeding surface is exposed. Sometimes this is done for the purpose of applying remedial agents. The false membrane of diphtheria appears most commonly upon the throat and nose, but it may be found upon the eye, vagina, or skin wound.

This is the disease *par excellence* for explaining the effect of toxins extracellular and separable from the bacteria. The organisms do not enter the body, but

only their toxins are absorbed and are responsible for the clinical symptoms of the illness, such as moderate fever with rapid pulse and great prostration. They are also responsible for the paralyses which frequently follow an attack, such as heart weakness or laryngeal failure.

Diphtheria is contracted by receiving, on a susceptible surface, some of the bacteria themselves. They usually come from an active case. However, after recovery from the attack, at a time when no symptoms exist, fully virulent bacteria may remain in the throat for many days. People with such a condition are called "*carriers*," and strict hygienic measures are being taken now by all health authorities to prevent spread of the disease by such means. Coughing or sneezing dislodges particles containing diphtheria bacilli, and spreads the disease. Infection has been known to travel by milk, where the dairyman had a case on his farm. The milk had become infected by those handling it. Nurses and doctors contract the disease frequently by their close association with the patient. They can protect themselves while inspecting a throat by placing a piece of glass before the patient's mouth so that if he cough the organisms will not get into the examiner's face. The absolute isolation of patient and nurse is now demanded by health authorities.

All materials that can be so treated should be burned. Utensils and fabrics should be soaked in carbolic acid solution and then boiled. Great care must be used by the nurse with her hands, face, nose, throat, hair, and clothes. The lodgement of diph-

theria bacilli in the hair is of special danger, since they remain active for a long time. To prevent the settling of the bacilli in the hair it is advisable to wear a cap that will completely cover the head. Thorough washing with soap and water, rinsing in hydrogen peroxide, 5 per cent., and drying in the sun are advisable when

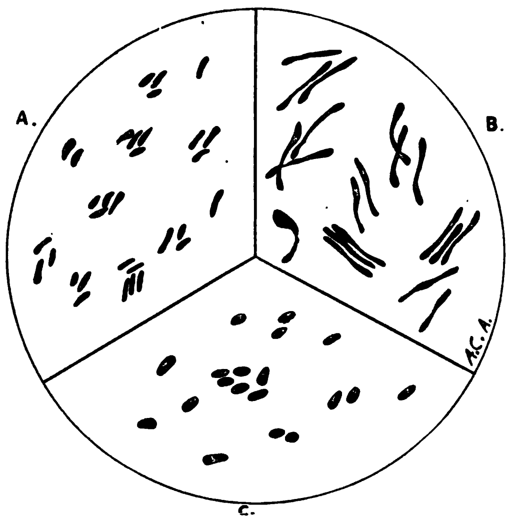


FIG. 32.—Bacterium diphtheriæ: *A*, its morphology on glycerin-agar-agar; *B*, its morphology on Löffler's blood serum; *C*, its morphology on acid-blood serum mixture. (Abbott.)

the nurse leaves the patient. The nurse should receive immunizing doses of antitoxin. Since the bacilli spread through the air, sheets wetted with disinfectants should be hung about, particularly at doors.

For diagnosis of diphtheria use is made of direct examination of stained smears from the site of trouble,

and cultures upon blood serum, the best culture medium.

The bacilli are rather characteristic in their irregular shape. They are rods of unequal length and width, full of granules, which stain more deeply than the rest of the rod. Their ends are usually clubbed or the whole rod may have the shape of a wedge. They may be straight or bent. They vary from $\frac{1}{40000}$ to $\frac{1}{2000}$ of an inch in length, and from $\frac{1}{50000}$ to $\frac{1}{25000}$ of an inch in breadth. They are very apt to show peculiar, more or less characteristic forms of degeneration. A special stain called Löffler's alkaline methylene-blue solution is used to show the peculiarities of their structure. The diphtheria bacilli are non-motile, non-spore-bearing rods. They are not pronounced in their manifestations of life under artificial conditions, except for toxin production, but they grow readily on most laboratory culture media. Solidified blood serum is the preferred artificial foodstuff. Upon it they grow in such a manner as to render diagnosis easy, both by the naked-eye appearance and by their shapes under the microscope. These bacilli grow best at the body temperature, 37° C. or 98° F., but also at a lower point.

They are killed at 58° C. or 140° F. for ten minutes. Boiling kills in one minute. In the dry state, protected from daylight, these organisms may live several months. With such protection, when moist or in exudate, as from the throat, life may persist for at least four months. Direct sunlight kills within half an hour. On cloth or other absorbing material their life is long, but indeterminate. On coins they die in twelve to

thirty-six hours. On toys, lead- and slate-pencils and tumblers they may live several weeks. They do not live long in cultures unless frequently transferred to fresh food. They resist cold. These data concerning the viability of the Klebs-Löffler bacillus in the outer world help to explain the sudden and otherwise inexplicable outbreaks of diphtheria, and the difficulties of their eradication. To disinfectants they present a slightly greater resistance than most non-spore-bearing bacilli. Carbolic acid, 1 to 100, kills in ten minutes; corrosive sublimate, 1 to 1000, in twenty minutes. Hydrogen peroxide kills them rather easily. These figures are for bacteria suspended in water.

Diphtheria bacilli will kill most experimental animals, but the guinea-pig is the most susceptible. Here they characteristically produce a sloughing at the site of inoculation, a peritonitis, and a congestion of the adrenal gland. Sometimes organisms suggestive of diphtheria bacilli are found in the throat without a membrane. In order to prove if these be true diphtheria forms, some of a culture is injected under the skin of a guinea-pig. If the changes described are produced, and the animal dies in three days, it shows that the organism in question was a true virulent diphtheria bacillus.

Diphtheria Antitoxin.—The specific poison of the organisms and the means used to neutralize it must now be discussed. The poison of the diphtheria bacillus is not only made in the false membrane in the human case, but is elaborated by the organism in artificial media in a laboratory. This poison itself will kill the lower animals. The toxin is obtained by growing the

germs on broth, made in a manner found most suitable for its development. The broth is freed of bacterial bodies and injected into horses. This animal is chosen for its size and freedom from disease affecting humans, and because large quantities of material may be injected and much blood withdrawn without harming the beast. The horses receive under the skin gradually increasing amounts of this toxic broth until they are able to withstand huge quantities, many times the dose necessary to kill them if given at first. They are then considered to have some neutralizing substances for this toxin. This neutralizing property is known to be in the blood serum. The horse is then bled, and the serum separated from the red blood cells. It is tested against the original toxin used for making the injections. This is done by mixing the two in definite parts, allowing the mixture to stand a few minutes, and injecting it into guinea-pigs. By appropriate technic the number of "units" is determined. A "unit" is that quantity of horse serum, or antitoxin, which will neutralize 100 times the smallest quantity of toxin necessary to kill a guinea-pig weighing 250 grams (8 ounces).

The horse-serum antitoxin has now a value for clinical purposes, as the quantity to be given can be controlled. Newer methods have permitted the refinement and concentration of this antitoxin, so that there is now less inconvenience in giving it. The dose for treatment varies from 1500 to 5000 units by injection under the skin. In bulk this may be less than a teaspoonful. For immunizing purposes, that is, to protect persons exposed but not yet suffering from the disease, from

300 to 1000 units are used. In both cases a repetition of the dose is frequently demanded, and in case the exudate does not fade, the injections may have to be given several times. The effect is a passive acquired immunity, as it is the addition of a toxin-neutralizing substance to aid tissues, for which they themselves have not worked. The visible effects of antitoxin administrations are a rather rapid disappearance of the false membrane, a fall of temperature, and a lessening of constitutional prostration.

For the best results in the treatment of diphtheria, antitoxin should be used early. Each hour of delay in using it after the diagnosis has been made reduces the good chances of the patient. For large cities the decrease in mortality has been 50 per cent., and in the favorable cases, even 75 per cent.

Pseudodiphtheria Bacilli.—There is a group of organisms called pseudodiphtheria bacilli, because of their resemblance in morphology and growth to the true disease-producing type. They are sometimes found in jaw abscesses or otitis media. They do not produce the typical diphtheritic sore throat. The presence of such forms in the throat often leads to erroneous diagnoses, and lengthens quarantine. Quarantine is demanded by health authorities until the throat is shown to be clear of diphtheria bacilli.

BACILLUS TETANI.

Tetanus or lockjaw is a disease characterized by tonic and clonic spasms of the muscles due to the effect of the soluble poisons of the *Bacillus tetani* or tetanus

bacillus upon the central nervous system. This poison, like that of the diphtheria germ, is separable or extracellular. It is produced by the bacteria, absorbed along the motor nerves, and carried to the brain and cord. Tetanus bacilli enter the body almost invariably by punctured or lacerated wounds. They multiply in the deep, covered position afforded by such wounds, but are not themselves taken up by the blood to be distributed throughout the body, only their poisons being absorbed. The bacteria are common in soil, manure, dust from covered places, wood, and the like. Their vitality is considerable, due to the formation of resistant spores.

Wounds carry the germs beneath the skin, where they lie covered and hidden in the deeper tissues. They do not grow in the presence of oxygen (anaërobic), so that a secluded place in the depths of wounds favors their development and that of their toxin. Simple uncomplicated, open wounds are probably never the site of development for tetanus bacilli. If other germs are introduced the tissues are further devitalized by them, and they absorb any available free oxygen, so that favorable conditions for tetanus are increased. Either spores or vegetating germs may be introduced on rusty nails, splinters of wood or glass, blank-cartridge plugs, or the grinding of dirt into wounds. Tetanus sometimes appears in the newborn or in the puerperal mother, particularly after instrumental delivery. Ordinary gelatin, sometimes injected under the skin to arrest hemorrhage, is said to often contain spores.

Between the time of introduction of the germs and the outbreak of symptoms a period of incubation

elapses which may be as short as three days or as long as six weeks. The muscles nearest the wound are affected first, as a rule, but the characteristic symptoms of lockjaw soon appear. After death very little is to be found by postmortem.

The danger from patients with tetanus is quite inconsiderable, the only infective material being the discharges from the wound or the pieces cut away surgically. Such objects are used for injection into animals to establish a diagnosis. This, however, is seldom necessary, as tetanus is quite clear in its symptomatology. All dressings and pieces removed surgically must be burned with actual fire. Boiling and baking are unreliable. The first treatment usually undertaken is the surgical cutting away of skin and subcutaneous tissue far beyond the original wound, in order to remove all bacilli. If these are removed no more toxin can be made.

The tetanus bacillus is large, $\frac{1}{12500}$ to $\frac{1}{5000}$ inch long by $\frac{1}{50000}$ to $\frac{1}{30000}$ inch wide; it is a motile, spore-bearing bacillus, growing only when the atmospheric oxygen is shut out. The motility is due to flagella arranged all about the cell wall. The spores develop at one end and give the rod a drumstick appearance. They are best seen in old cultures. The spores may leave the parent bacillus and lead an independent existence. In this state they are not motile, and are stained with great difficulty. The vegetative rod, however, stains with comparative ease. The organism can digest gelatin and grows characteristically in it.

In discussing the resistance of this germ to deleterious agents, the spores only need be considered, because

the vegetative rod has the power of going into this resistant stage very quickly when it meets unfavorable environment. The rods grow best at 37° C. or 98° F. The spores are killed at 105° C., 221° F., when exposed ten minutes to streaming steam. They are destroyed by chemicals as follows: 5 per cent. carbolic acid in ten hours; 5 per cent. carbolic acid plus 0.5 per cent. hydrochloric acid in two hours; 1 to 1000 corrosive sublimate in three hours; 1 to 1000 corrosive sublimate

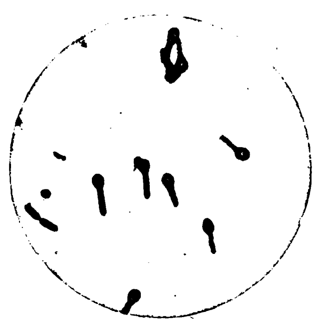


FIG. 33.—Tetanus bacilli with spores in distended ends. × 1100 diameters. (Park.)

plus 0.5 per cent. hydrochloric acid in one-half hour; 1 per cent. silver nitrate in five minutes. When dried the tetanus spores will live several years. Sunlight very slowly kills them. Most animals are susceptible to the tetanus bacillus or its toxins. Rats and birds are the least, while horses and man are the most sensitive.

Tetanus Antitoxin.—The toxin of the tetanus bacillus is one of the most virulent poisons known. For example, $\frac{1}{10000000}$ cubic centimeter or $\frac{1}{625000}$ minim

has been known to kill a mouse. It is composed of two parts, one the major, with a primary irritating and secondary paralyzing effect on the central nervous system, and a minor part having a solvent action upon the red blood cells. These poisons develop both in wounds and on laboratory culture media. The methods for procuring this poison are essentially those described under Diphtheria, and similar methods are used to immunize horses against it. The antitoxin is in the immunized horse's serum, and is refined and used in the same general manner as diphtheria antitoxin. The unit in this case is the quantity of antitoxin necessary to neutralize 1000 times the smallest dose of toxin required to kill a guinea-pig weighing 350 grams, 11⅔ ounces. The conditions of administering antitoxin for tetanus are somewhat different from those in diphtheria. In the latter the posion is largely circulating in the blood, while in tetanus some of it is at the point of infection, some in the muscles and nerves and central nervous system, and the least part is in the blood. To reach all of these places it is necessary to make injections into the vein and under the skin as well. The surgeon attempts to reach those parts first which have been affected the longest, to halt at once any further damage there, and therefore methods of treatment vary. Antitoxin is sometimes injected directly into the nerves in order that some may neutralize what toxin is remaining in them along their length or in their muscle distribution. In severe, rapidly developing cases it may be injected into the meningeal space or directly into the brain tissue.

It is best to give 10,000 units by the vein and repeat

at several-hour intervals until symptoms start to abate. The sooner after the symptoms appear that antitoxin is given the more favorable is the outlook. Antitoxin is now given freely by health authorities, to all who receive firearm wounds about July 4.

BACILLUS TYPHOSUS.

Typhoid fever or enteric fever is an acute infectious disease caused by the *Bacillus typhosus* or typhoid bacillus circulating in the blood and settling in the various organs, particularly the lymphatic structures of the small intestines.

The bacteria enter the body *via* the mouth and are able to pass the stomach into the small intestines. Here they are taken up by the lymphatic organs, which immediately begin to swell. This reaction brings more blood to the part and the circulation soon contains the germs. The incubation period is that time elapsing between the introduction of the typhoid bacillus into the alimentary canal and the first positive signs that it has been taken up and disseminated by the blood stream. Then there are gradually increasing fever, malaise, a relatively slow pulse, distention of the abdomen, diarrhea or constipation, rose spots, and other signs of the true infection. The incubation is about two weeks. The bacteria, while not true pus-formers, do cause a breaking down of tissue. This is characteristically seen in the lymphatics of the small intestine called Peyer's plaques. These bodies swell toward the free lumen of the canal, and the centre finally softens from the effect of the bacilli. When

the softened part separates and is removed, a ragged, punched-out ulceration remains. This ulceration may be progressive and eat into bloodvessels, causing intestinal hemorrhage so common in this disease. If the ulceration be directed out toward the peritoneal surface of the intestine, perforation and peritonitis may ensue. The presence of the typhoid bacilli and their toxins in the organs, notably the spleen, causes characteristic changes which need not be dwelt upon here.

Typhoid fever is more common in men between the ages of twenty and thirty-five years. Spring and autumn are the seasons of greatest prevalence. It spreads from patient to patient usually through the intervention of food and drink and accidental or chronic carriers. Water and food polluted by flies that have soiled their bodies upon excreta, form the greatest sources of indirect propagation. Water is polluted by the dumping of sewage containing typhoid germs into a water course used as a drinking supply. Typhoid bacilli can live within a particle of feces over the winter, so that the infection of a water course in the spring is not to be wondered at. When winter breaks up the spring rains wash down the hillsides, sweeping before them surface collections into streams. The greatest danger, however, exists when towns empty their sewerage systems into a stream from which other communities lower down take their domestic supply. This means of spread is proven by the fact that when known infected sewage is no longer dumped into a water supply typhoid fever ceases to be prevalent among the users of the water. Ice is said to be another

method of transmitting this disease. It is best not to inculpate the ice itself, since freezing kills whatever germs are not squeezed out in the contraction of the water when becoming solid, but rather blame the dirty methods of cutting, storing, and distributing. Ice not infrequently becomes covered with manure and earth in storing and lading for distribution. The unwashed hands of the ice-man are only too familiar. When ice is placed in the water cooler in public places it is frequently washed under a spigot and then picked up in the hands of the distributor.

Typhoid bacilli do not multiply to any considerable extent in water, but merely remain viable. Milk is a prolific source of spread, since it is easy for the dairyman with a case of typhoid on his farm to infect this product. Fresh milk has a mild restraining effect upon typhoid germ growth, but does not kill many. The bacilli do not come from the cow, but are introduced somewhere in the route from her to the consumer. Vegetables grown in ground upon which infected manure or water has been spread may carry the disease; such as, for instance, water-cress, lettuce, tomatoes, or others that are eaten raw. Oysters fattened in water contaminated by sewage are said to transmit the disease.

House-flies may settle upon human excreta in outhouses or toilets or in sick-rooms, and by walking on articles intended for food, leave behind some of the germs.

The personal contact of nurse, physician, or a member of the family must never be underestimated as a means of direct transmission. Indeed, it is looked upon by

some authorities as the most important and fruitful method. Upon bed-pans, glasses, eating utensils, bed linen, or clothes there may be a few bacilli lurking, which can easily be conveyed to the mouth by persons handling these objects.

The typhoid bacilli may lurk in the body, probably in the bile passages, for a long time after the attack. For this reason disinfection of stools and urine should be continued for at least two months after the patient is well. Such people as may spread the disease by this means are called "*carriers*." There are also cases on record in which persons who never suffered with typhoid fever have excreted the bacilli in their stools. It is probable that these persons have had sufficient resistance to overcome intestinal disease, but the germs have infested the bile passages and passed down them to be mixed with the excreta. Two such cases are known to the writer, one of which had a history of having nursed her husband in a fatal attack of typhoid, but whose personal history is free of any illness suggesting this disease.

Measures for preventing infection should be directed toward killing all the typhoid bacilli, not such a difficult task. Infective material consists of feces, urine, expectoration, and possibly perspiration. Any of these may infect bed or body linen, and the last can spread the bacilli on dishes or hands. All discharges should be received in carbolic acid solutions, well mixed and allowed to stand half an hour before emptying into a drain. Clothing of all kinds should be soaked in carbolic or corrosive sublimate solution for an hour, and then boiled. The same procedure should be followed

with glasses and eating utensils. The mouth should be washed or wiped with boric acid solution frequently. A dish of bichloride, 1 to 2000, should be convenient, so that the nurse or visitor may cleanse the hands frequently.

The typhoid bacillus is an organism exerting its noxious power by means of poisons contained in its body and liberated upon its disintegration. These

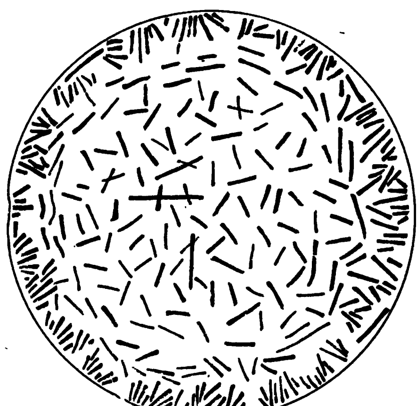


FIG. 34.—Microscopic field, showing the top of a hanging drop in a normal typhoid culture. (Park.)

endocellular poisons are capable of calling forth a reaction upon the part of the body which results in some antibody formation. Second attacks of typhoid are rare and the reason is probably that a sort of active immunity is gained by one attack. As a matter of fact, it can be shown by laboratory methods that blood after typhoid fever has more power to destroy the bacilli than before the attack; that is, it has

more bacteriolysin than is possessed by the blood of a person who has never suffered from typhoid.

Widal Test.—Far more important antibodies are the agglutinins used extensively in the diagnosis of the disease. These are bodies in the blood which when brought into contact with the bacilli, make them stop moving and clump together. To use this for diagnostic purposes a fluid culture or salt solution sus-

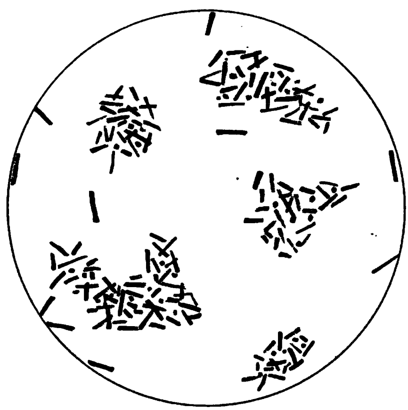


FIG. 35.—Microscopic field, showing the top of a drop with the typhoid reaction. (Park.)

pension of the living, actively motile germ is prepared. Some blood from the patient is obtained, the clear serum collected and mixed with the bacterial suspension in dilution of 1 part of the serum to 20, 50, 100 or more parts of the bacterial suspension. These dilutions are used because sera from some persons entirely free from typhoid will clump the bacilli in low dilution, 1 to 5 or 1 to 10. The mixture of serum and bacteria is

observed under the microscope after they have stood together for a definite time, and the presence of clumping, with loss of movement, noted. In case this occurs typhoid is present. This agglutination reaction is called the Widal test, and is positive in about 95 per cent. of all cases (see Figs. 33 and 34.)

Cultures.—It is also of aid in the diagnosis of typhoid to make a blood culture. This consists in withdrawal, under sterile conditions, of blood from a vein, placing

FIG. 36.—Typhoid bacilli from nutrient gelatin. × 1100 diameters. (Park.)

it into suitable culture medium, and keeping it at body heat in the incubator. If typhoid bacilli be present they will grow so that we may isolate and identify them. The bacilli may be isolated also from the feces and urine during an attack, and as mentioned above, for a long time afterward in the case of carriers. The methods for isolation are tedious and difficult, and need not be described here. Many technics have been devised to hasten work on epidemics and carriers, but none is as yet very good.

Morphology.—The typhoid bacillus is a motile rod $\frac{1}{25000}$ to $\frac{1}{8000}$ inch long and $\frac{1}{50000}$ to $\frac{1}{30000}$ inch wide, with rounded ends, growing in long threads at times. Its motility is due to flagella all around its cell wall. It forms no spores. It stains easily, oftentimes more densely at the rounded ends. It grows in the presence or absence of oxygen, best at 37° C. or 98° F., but also at room temperature. It is killed by heating at 60° C. or 142° F. for five minutes, or to 52° C. or 126° F. for

FIG. 37.—Typhoid bacillus with faintly stained flagella. (Löffler's method.) (Park.)

ten minutes when in water suspension. It usually dies rapidly when dried, but occasionally lives for some weeks. It is killed in watery suspension by 1 per cent. carbolic acid or 1 to 1000 bichloride in ten minutes. Its characters in laboratory culture media are not easy to describe, and indeed the trained observer is often puzzled to identify it. Suspected cultures are usually subjected to the Widal test, using the blood of a patient with typhoid fever, and known to clump a true typhoid

bacillus. The bacillus belongs to the so-called typho-colon group (see p. 177). The lower animals do not develop typhoid fever when inoculated with this germ, but die of septicemia, usually with peritonitis.

Immunization.—An antitoxin to the typhoid bacillus cannot be produced, but attempts at active immunization have been made with some success. These attempts take the direction of injecting the bacilli in such a form that they cannot produce the disease, but yet set up some resistance to it comparable to that acquired by passing through a spontaneous attack. The bacilli are prepared like the vaccines or bacterins described on p. 76, and injected under the skin. A slight fever may result, but no further bad effects have been noted. All symptoms are over in twenty-four hours after each injection. The bacteria are introduced three times in quantities of 500,000,000, 1,000,000,000 and 1,000,000,000 at ten-day intervals. The immunity resulting is supposed to last about two years. This vaccine method is well adapted for and most used by armies going into camps. The results in our army and that of Great Britian have been very encouraging. It should be taken by nurses doing army nursing or seeing many typhoid cases.

Major Russell, U. S. A., concludes his investigations into the theory and practice of antityphoid vaccination as a prophylactic as follows:

1. Antityphoid vaccination in healthy persons is a harmless procedure.

2. It confers almost absolute immunity against infection.

3. It is the principal cause of the immunity of our troops against typhoid in the recent Texas maneuvers.

4. The duration of the immunity is not yet determined, but is assuredly two and one-half years and probably longer.

5. Only in exceptional instances does its administration cause an appreciable degree of personal discomfort.

6. It apparently protects against the chronic bacillus carrier and is at present the only means by which a person can be protected against typhoid under all conditions.

7. All persons whose profession or duty involves contact with the sick should be immunized.

8. The general vaccination of an entire community is feasible and could be done without interfering with general sanitary improvements, and should be urged wherever the typhoid rate is high.

By the use of this prophylactic, typhoid fever has practically disappeared from the United States Army.

Vaccines have also been used during an attack of typhoid, but the results, while satisfactory to some observers, cannot be said to be generally acceptable.

Paratyphoid Fever.—There is a variety of enteric fever called paratyphoid fever. This is caused by the *Bacillus paratyphosus*, an organism closely allied to the true typhoid bacillus and only separated from it by its ability to ferment certain sugars and the quantity of acid it produces under artificial conditions. In paratyphoid fever, however, the blood will not clump (agglutinate) the true typhoid bacillus, but does have such an action upon the paratyphoid bacillus. In this form of fever the course is shorter, the attack is milder, and complications are much less frequent. There is usually no ulceration of Peyer's plaques and therefore hemorrhage from the bowel is of extreme

rarity. It is nevertheless an infectious disease, entirely comparable in its origin, course, transmission, and epidemic character to true typhoid fever, and the same precautions of disinfection must be observed.

MICROCOCCUS MELITENSIS.

Malta fever is an acute infectious septicemic disease, endemic along the Mediterranean, following a course similar to typhoid fever, but usually of less serious nature. It is caused by the *Micrococcus melitensis*. Goats harbor the organisms and pass them out through the milk, an important food in Malta. Persons can be infected by introduction through a wound. It is probably not transmitted from man to man. The diagnosis is made by means of blood cultures or by the agglutination test. The bacteria are of rather elongated shape, by some observers taken to indicate that they are bacilli. They are about $\frac{1}{75000}$ inch long, single or in pairs. No motility is seen, and no spores are formed. They stain easily and grow well in ordinary media at 37° C. or 98° F. Monkeys are the only animals which can be artificially infected. Vaccines of dead cultures may be used. The bacilli are killed by the same methods as the typhoid bacillus.

BACTERIUM INFLUENZÆ.

Influenza is also called la grippe or grip, and is an acute catarrhal disease usually involving the mucous membrane of the upper respiratory tract, but also penetrating to the deeper parts. Its causative

PLATE IV

Bacterium Influenzæ in Sputum. (Abbott.)

bacterium is the *Bacterium influenzæ* or the influenza bacillus. The disease is one which appears in epidemic form usually, but sporadic cases also occur. The organisms are carried in the nose and throat and communicated to others in the fine particles coughed or spat out. They lodge on the mucous surfaces and produce an inflammation through which the poisons are absorbed. The rods themselves do not usually enter the blood stream, but they may do so, as is attested by the fact that there are influenzal forms of pleuritis and pericarditis, diseases probably not due to an extension by continuity. Influenzal pneumonia occurs when the bacteria penetrate to the lung tissue proper. It is comparable in development to the pneumonia caused by the pneumococcus. The bacillus may at times form pus.

A very important and highly fatal form of influenzal infection is meningitis due to a blood distribution of the organisms in cases of pneumonia or other local lesion, but at times arising without previous history of illness. The disease is clinically similar to epidemic meningitis and the fluid in the meningeal spaces is likewise purulent.

The attack of influenza runs an acute course. It leaves but a transient immunity, and one attack is said actually to predispose to another when the individual is exposed subsequently. As complications of influenza of the upper air passages we may have pus in the sinuses about the nose, or otitis media.

While influenza is an acute disease and the bacteria are actively virulent during an attack, it is believed that they remain in the upper air passages in abey-

ance and not producing disease for long periods after the acute symptoms have subsided. When they are received in sputum particles upon the nose or mouth of another person not resistant to them, they regain their activity and inflame the parts. It is said that they may remain in the lung tissue for a long time until some reduction of the person's resistance permits the lighting up of a pneumonia.

With these facts in mind it is not difficult to understand how sporadic cases occur and how the disease spreads rapidly from one patient to another. The bacilli get to work on the mucous membranes rapidly, and the incubation period is short, three days at the longest. Epidemics have been known to spread over whole continents in a season. Many observers believe that other organisms, notably streptococci, help in the production of these acute influenzal colds. It is undoubtedly true that the influenza bacillus is seldom found in pure culture, that is, in absence of some other organism with pathogenic properties. The bacilli are found in the excretions and secretions from the nose, mouth, and lungs. All excretions should be received into carbolic acid solution, and the mouth and nose frequently douched with a mild antiseptic. The nurse and members of the family should use care with the nose and mouth in frequent rinsing with weak antiseptics, such as hydrogen peroxide. For diagnosticating this disease smears and cultures are made from some of the glistening mucus at the back of the throat or a good specimen of sputum coughed from the lungs. The smears on slides are stained with appropriate dyes. Under the microscope the delicate rods are found in pairs on end,

lying in groups or within the pus and epithelial cells. In cultivating these organisms media containing whole blood or blood coloring matter, hemoglobin, must be used. They will not grow in the absence of the latter, and the colonies upon solid media containing it are rather characteristic. During an attack the bacteria produce some agglutinins in the blood and the agglutination or clumping test may be used with them. This is not highly practical and seldom used.

The influenza organism is a very minute rod with pointed or round ends and commonly lying in pairs with their ends together. They do not move nor form spores. They measure about $\frac{1}{50000}$ inch long and $\frac{1}{100000}$ to $\frac{1}{75000}$ inch wide. They require oxygen for growth, which occurs on blood-containing media as fine dewdrop-like colonies. Their general biological characters offer fine details not needed here. They require body heat, 37.5° C. or 98° F., for development, and are killed at 50° C. or 122° F. for ten minutes; 60° C. or 142° F. kills at once. They die in twelve hours if dried in sputum, but may live without multiplication for several days in moist sputum at ordinary temperature. Five per cent. carbolic acid kills them in well-mixed sputum in five minutes. For animals this bacterium is not very pathogenic. Rabbits and monkeys, if injected into the vein with a pure culture exhibit very quickly signs of an intoxication, which rapidly passes away. Monkeys may get an acute cold by the direct application of the bacilli to the abraded mucous membrane of the nose. For the treatment of acute influenzal colds there is no practicable specific therapy by the use of

antisera or bacterins. When, however, there is a prolonged catarrh of sinuses, larynx, or bronchi, or when it can be shown that a person is harboring the bacilli, it is perfectly feasible to employ dead organisms as a bacterin, using, wherever possible, a culture from the patient. This is practically never in pure cultures and mixed vaccination is the rule. For pneumonia, pleurisy, and so forth we know nothing of the practical nature of antiserum, but for meningitis it has been found to have some curative effect. It is introduced into the spinal canal after withdrawal of some fluid to make room for it. It is made by injecting horses with increasing numbers of the bacilli and separating the serum as for diphtheria antitoxin.

BACILLUS PESTIS.

Bubonic plague or "the plague" or "pest," is an acute infectious disease caused by the *Bacillus pestis*, and characterized by high fever, suppuration, swelling of the lymph glands, and a severe grade of bacteremia. In the so-called pneumonic form, a pulmonary inflammation dominates the clinical picture, but the infective nature of the disease is the same. Occasionally, in very severe attacks, subcutaneous hemorrhages occur; this is called "black death." The commoner or lymph gland form occurs where the bacteria gain entrance by skin cracks or wounds, while the pneumonic type follows inhalation of the germs.

The bacteria enter chiefly through the skin by way of minute wounds, or, as was shown in India, by the bite of a rat flea. Rats and mice, indeed all rodents,

PLATE V

A

B

Bacillus of Bubonic Plague. (Abbott.)

A, in pus from suppurating bubo; *B*, the bacillus very much enlarged to show peculiar polar staining.

are susceptible to plague, it practically being endemic among them in certain countries, and they contract it from biting the living, feeding on the dead, soiling themselves on dressings or excreta, but principally by their parasitic fleas. When infected they have great numbers of bacilli in their blood, thus easily passing them on to fleas that bite them. The fleas then pass the disease to other rats and to man. Furthermore, rats may vomit, defecate, and die where they can infect objects later handled by persons. The rats are said to transmit the disease also by biting people. In epidemic times the ground becomes infected, and persons going bare-foot may be infected. By any of the skin-wound methods, the germs enter the subcutaneous tissue, are carried to the nearest lymph glands, where they set up inflammation and pus, which is frequently discharged by rupture through the skin. The bacteria enter the blood stream and produce a septicemia.

In the pneumonic form the bacteria are inhaled and set up a pneumonia not unlike that produced by ordinary cocci. Here, again, there may be suppuration and septicemia.

The bacilli produce the characteristic results chiefly by means of their endotoxins, little or no separable poisons being formed. There is no difference in the bacteria or their products in the two forms, these simply depending upon the mode of entry. The mortality of this disease is very high, due to the rapid progress made after the disease gains a foothold. The incubation is three to seven days. The bacteria are present in the blood, pus, and sputum in enormous

numbers. They may be also in dejecta. Many suppose them to be in the breath, but this is probably erroneous. They are in the droplets of saliva expelled by coughing, sneezing, and talking. It is customary in times of epidemics to go about with a towel over the nose and mouth, with the feet and ankles well bound, and all surfaces covered. Sputum, urine, and feces should be received into 5 per cent. carbolic acid and allowed to remain, well mixed, for two hours. Dressings from ulcerated surfaces must be burned. Doors and windows must be screened against flies and mosquitoes. The room must be rat- and mouse-free. After death formaldehyde or carbolic acid solution is to be injected into the body entrances and applied about the body on the winding sheet.

For diagnosticating this disease an abscess is punctured, the pus withdrawn, and slide smears and cultures are made. The bacilli are found in countless numbers. Cultivation on ordinary media is simple. A blood culture will also reveal their presence. At death bacteria will be found in practically every organ in the body.

The plague bacillus is a short plump rod, $\frac{1}{17000}$ to $\frac{1}{13000}$ inch long by $\frac{1}{50000}$ to $\frac{1}{30000}$ inch wide. It does not move nor form spores. It grows best at 35° C. or 92° F. It is stained with reasonable ease, displaying a peculiar picture. The bacilli are short, thick rods with rounded ends. The end sections stain much more densely than the middle part, called bipolar staining. These rods may grow longer and appear in pairs or short chains. They are killed by 60° C. or 142° F. in ten minutes, or by boiling water in two

minutes. They resist drying for two or three days under natural conditions, but when drying is hastened by artificial means, they live only a few hours. They resist cold and freezing for a long time, perhaps a month. Sunlight destroys them in five hours. In pus or sputum they may live a few weeks, but in cadavers they have been found after several months. Chemicals kill them as follows: 5 per cent. carbolic acid and 1 to 1000 bichloride in ten minutes. Animals are usually susceptible to *Bacillus pestis*, particularly guinea-pigs and rats, and it is said that simple rubbing of the germs on the skin of these beasts will produce the infection. It is similar to the human disease.

Plague Serum.—The poison of *Bacillus pestis* is largely intracellular. It has been possible to get an antiserum from horses which will destroy the bacteria and can be used therapeutically. The bacteria grown in the laboratory are killed by moderate heat and injected into animals. The injections are continued until very large doses, fatal to unprepared animals, are withstood. The serum now has properties which will neutralize the endotoxins of the plague bacillus, and is called a bactericidal serum. It is said to have also some antitoxic properties that neutralize the small amount of extracellular poison of this organism. This serum is used for treatment during the attack or for immunizing those exposed. The serum is injected under the skin for preventive purposes, but during an attack it is well to give it into the circulation.

Not only is this passive immunity made use of, but for prevention of infection, plague bacilli whose pathogenic properties are destroyed by heat are also injected

precisely as has been described for typhoid fever. This "vaccine" prophylactic, and one of the first of such procedures, gives an immunity for a few months. Immunity against a subsequent attack always follows plague. Thus there is an active immunizing therapy for plague, and passive immunizing substances can be added to the patient's own defenses.

SPIRILLUM CHOLERÆ ASIATICÆ.

Cholera is an acute inflammatory disease of the small intestines characterized by profuse watery stools, a profound prostration, muscular pains, and high fever. It is caused by the *Spirillum choleræ asiaticæ* or cholera spirillum or vibrio. The bacteria enter the body only through the mouth, and settle upon the mucous membrane of the lower part of the small intestine. This they penetrate only as far as the deeper layers of the innermost coat of the tube, and by their growth cause a shedding of the lining. The shreds of the desquamated mucous membrane pass off with the watery discharges, and cause the characteristic "rice-water" stools. The bared and congested surface permits absorption of the poisons of the spirillum, the body of which does not itself enter the blood stream. The poison quite frequently has a depressing action upon the heart muscle. It is not quite certain whether or not this is a wholly extracellular toxin or combined closely with the bacterial bodies. It is probably mostly of the latter character, an endotoxin separated upon the disintegration of the germ cells.

Cholera is a disease transmitted almost exclusively

by polluted water, although food infected with bacteria may, of course, transmit it. Water is contaminated by dejecta of cholera patients, and the vibrio leaves the patient in no way but with feces (or vomiting of intestinal contents, a rare occurrence). Large numbers of vibrios are present in the feces early in the attack. Later they rapidly decrease, but do not disappear from the gut and feces, and may continue to come away in small numbers for many months. In such cases they naturally pollute anything with which the dejecta come in contact. They do not live long in nature, however, and regulations can be made to kill them. Flies having soiled themselves upon cholera excreta may carry the germs. Vegetables may be soiled from water. Personal contact and handling of clothes from patients have the same value in transmission of cholera as for typhoid fever. As the organisms leave the body only with the feces, measures should be taken to disinfect them, and anything likely to be soiled with them. The feces should be received into 5 per cent. carbolic acid solution. The buttocks and anus should be wiped with 1 to 1000 bichloride solution. Clothes or bedding, glasses, utensils, and other objects should be soaked in these solutions. Boiling when possible is advisable. A disinfecting hand lotion should be constantly used by the attendants. It is necessary to continue disinfection of stools for varying periods after an attack, since bacteria lurk in the depths of the intestinal mucosa, and are excreted long after the acute symptoms have disappeared.

Cholera is diagnosticated bacteriologically by cultivation of the stools. The organisms are present in

almost pure culture, and can be made to grow quite easily. There are several other spirilla of similar form and manner of growth, and sometimes delicate biological tests (see below) are necessary. Agglutination tests may be used in this disease, as some clumping power is acquired by the blood during an attack. Another antibody, a bacteriolysin, is formed, which has the power of dissolving the cholera spirilla. Animals injected with the cholera organisms also acquire this power. If a guinea-pig be injected with spirilla up to a point where it will resist large numbers, its blood serum will dissolve the living organisms either in the test-tube or, what is better, within the abdominal cavity of another guinea-pig. In the latter case the antiserum from the prepared guinea-pig and living rods are mixed and injected together into the peritoneal cavity. The rods are devitalized and the pig lives, although another animal receiving the organisms in like quantity, but without serum, will die. This is the method suggested which can be used to identify suspected cultures, using as the protective blood serum that from an animal previously treated with known cholera germs.

The cholera spirillum is a curved organism something the shape of a comma, and is sometimes called the comma bacillus. One end is apt to be thicker than the other. It sometimes appears like an S when two are joined on end. Long filaments may be seen in fluids. In old laboratory cultures it may appear as a short, straight rod or club. It is actively motile by means of a long single flagellum on the end. No spores are formed. It measures from $\frac{1}{8000}$ to $\frac{1}{5000}$ inch in

length by $\frac{1}{75000}$ inch in width. It is not easy to measure since spirilla are not simple curves but spirals. It does not stain with great ease, but a weak watery solution of fuchsin is the best. It grows best in the presence of oxygen at 37.5° C. or 98° F., but may grow at ordinary temperatures. It has the power of digesting gelatin and solidified blood serum, but does not clot milk. It resists 60° C. or 142° F. for one hour, but boiling kills

FIG. 38.—Spirillum of Asiatic cholera: *I*, stained by ordinary method; *II*, stained to show flagella. (Abbott.)

at once. It multiplies at the temperature of foodstuffs, and freezing does not destroy it under three days. Drying kills certainly in twenty-four hours in diffuse light. Sunlight kills within one hour. The figures indicate some resistance to heat and light, but against chemicals this is not maintained; 1 to 1000 bichloride is fatal in ten minutes; 1 per cent. carbolic acid a little longer; lime in any form is rapidly fatal to the spirillum.

Animals do not contract cholera either spontaneously or artificially, but they may be killed by the germs or their poisons. The active acquired immunity they get by repeated injections has been described. It has not been found practical to obtain any serum from animals which can be injected into human beings as a treatment. Dead spirilla, however, can be injected into well persons as a protective measure, precisely as is done for typhoid and plague, and with good results.

BACILLUS DYSENTERIÆ.

Dysentery occurs in two forms—the bacillary type and the amebic type. The former is caused by bacteria, while the latter is a protozoön disease (see Chapter XIV). Bacillary dysentery is an acute infectious disease, its chief lesion being a violent inflammation of the lining of the large intestines. The disease is caused by the *Bacillus dysenteriæ* or dysentery bacillus. It is, however, better to say that a group of organisms under this name gives rise to it because there are many varieties with different chemical and serum reactions, producing attacks of varying severity. Their general pathogenic and etiological effects may be discussed together, however. The usual ileocolitis of children is not due to the dysentery bacillus, but some members of the dysentery group have been found responsible for small epidemics of diarrhea among children.

In cholera the chief lesions are in the lower small intestine, but otherwise the two diseases have many things in common.

The bacilli enter probably only by the mouth in

infected food and drink, and pass through the alimentary tract to their organ of predilection, the colon. Here they penetrate the mucous lining to its deeper layers, causing violent irritation. They may get deeper into the wall or even to the glands draining the colon, but not into the blood. The inflammation gives rise to diarrhea which passes from feculent to mucus, to bloody mucus, and may be almost wholly blood. These effects are due to the effort of the colonic wall to rid itself of the poisons, and the body seems to choose this method to free itself of the intruder. This fact is further shown when we inject susceptible small animals with the poisons, for a congestion of the colon and diarrhea result, although no living organisms are present. The poisons of the dysentery bacilli are probably both extra- and intracellular, the latter being more abundant. The toxic effect, therefore, is exerted by the existence of the germs in the mucous membrane giving off poisonous products of their life, and to a greater degree, by the poisons liberated upon their disintegration. The poisons are absorbed into the blood, giving rise to an irregular fever in which sudden drops are common. This sudden fall of temperature may be observed in animals receiving doses of the poison.

Dysentery is transmitted like other diarrheal disorders, that is, by the pollution of food and drink by discharges of patients, since the germs leave the body only by the feces. Disinfection of excreta, clothes, utensils, and hands should be done as for cholera. After an attack persons may be carriers, and disinfection of stools should not cease upon clinical recovery.

The blood acquires some resistance to dysentery bacilli during an attack, comparable closely to the changes in cholera, that is bacteriolytic substances and agglutinins are to be found. Advantage of this is taken in immunizing the lower animals with toxins obtained in laboratory cultures. In order to discover if dysentery bacilli be present, laboratory cultivation of the stools is undertaken, using as material the bloody parts, mucus or shreds of membrane, in any and all

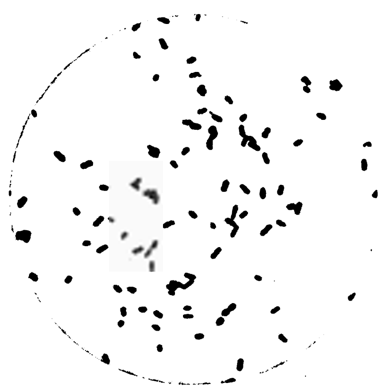


FIG. 39.—Dysentery bacilli. × 1000 diameters. (Park.)

of which the germs abound. The development in the laboratory is comparatively simple, but to identify the species or variety is anything but easy. The agglutinins in the patient's blood may be tested against pure laboratory cultures of known varieties, and thus a bacteriological diagnosis as to the type may be made. Thus, for diagnosticating dysentery we have only the feces culture and agglutination test. Since the bacilli are not in the blood, cultures of this are not made.

The dysentery bacillus is a short, straight, non-motile rod with rounded ends. It is quite like the typhoid bacillus in shape and size, but unlike this germ, does not move actively. It may at times show degenerated forms. It is usually single, but may be in pairs. It stains easily. It grows both aërobically and anaërobically, but better under the former conditions. Its growth upon laboratory media is also like that of the typhoid bacillus. Best development occurs at 37° C. or 98° F., and death results when 60° C. or 142° F. is held for ten minutes.

It resists freezing for a long time, possibly some weeks. It is killed by drying only after long periods. Its resistance to chemicals is practically the same as that of typhoid bacilli. Animals do not contract dysentery when they take the bacilli by mouth, but when germs or their toxins are introduced under the skin, into the vein or peritoneum, profound intoxication occurs, with fall of temperature, peritonitis, diarrhea, and in some cases hemorrhage in organs or body cavities.

Dysentery Antiserum.—Nevertheless, animals, notably rabbits and horses, have been made to withstand large doses by preparation with graded amounts. They develop sera containing antisubstances to both the endo- and extracellular dysentery toxins. This serum has been used therapeutically in the treatment of dysentery of the tropical variety, but it has not been found useful in other cases; it is made only against what is called the Shiga type of dysentery bacillus. Thus passive immunity can be secured, but so far no great success has met attempts to raise the resistance

of human beings to dysentery by injecting dead or attenuated bacilli; no active immunity has been achieved. The antiserum may also be used as a preventive, given subcutaneously in generous doses, particularly in times of epidemic. Our knowledge is incomplete as to its full value, but the reports so far are promising.

VINCENT'S ANGINA.

Vincent's angina is a very important inflammatory disease of the tonsils and pharynx, sometimes simulating diphtheria in that a false membrane is also characteristic of the disease. The causative bacteria are spirilla and fusiform rods, probably two stages of development of the same organism, since it is believed that the former develop from the latter. The earlier stage is the time when the pseudomembrane appears, but this soon gives place to punched-out ulcerations. The disease is mild, producing only a little local pain, slight fever, and malaise. The disease may coexist with diphtheria, aggravating the latter. The bacteria gain admission by direct transfer from a patient to the unaffected throat. The condition is not very contagious. Disinfection should be observed by frequent cleansing of throat and mouth by mild antiseptics. Rinse water and cloths used to wipe the mouth may be rendered innocuous by any practical disinfectant working for half an hour. Little is known of the method of action of the bacteria. They probably produce the condition by soluble poisons. In diagnosticating Vincent's angina a smear from the false

membrane stained with particular care will show long fusiform rods with sharp ends, taking the dye more deeply at the ends and in the form of transverse bands, and quite long, wavy, spiral organisms, usually having shallow, irregular curvatures. The bacilli are $\frac{1}{4000}$ to $\frac{1}{2000}$ inch long and $\frac{1}{40000}$ to $\frac{1}{30000}$ inch wide. They probably grow best under anaërobic conditions. There is no specific treatment.

FIG. 40.—Vincent's bacillus with accompanying spirochætæ. (Park.)

CONJUNCTIVITIS.

There are many bacteria capable of producing inflammations of the conjunctival sac, but there are a few that seem peculiar in being found only in this place. Whether they are separate species or not remains to be seen. The most important mild inflammation of the conjunctiva is the "pink eye." This acute con-

dition is transmitted by direct or indirect passage of moist infective material from one patient to another. Therefore an affected eye should be kept covered and dressings handled carefully. The organisms are killed by very weak solutions of the ordinary disinfectants, and, indeed, probably do not resist boric acid very long. The causative germ is the Koch-Weeks bacillus of conjunctivitis. It is similar in size, shape, and staining properties to the influenza bacillus, but differs from it

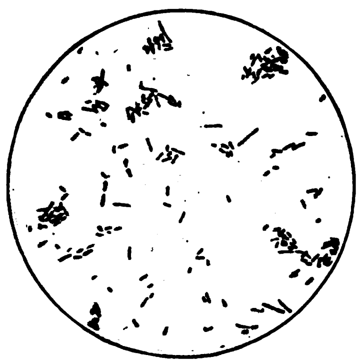


FIG. 41.—Koch-Weeks bacillus (pink-eye), 3d generation. × 1000 diameters. (Weeks.)

in that it will grow in the absence of hemoglobin, and with reasonable ease on ordinary culture media. It is destroyed at 60° C. or 142° F. in two minutes. It does not affect animals. There is no specific therapy.

Another form of conjunctivitis chiefly affecting the angles of both eyes and running a subacute course is caused by the bacillus of Morax and Axenfeld. These organisms as seen in smears made best from exudate collecting overnight, appear as short, end-to-end, ovoid

rods, each about $\frac{1}{12500}$ inch long. They may be cultivated at body temperature on media containing blood or blood serum. They produce disease by their presence and by some form of toxin little understood. The disease does not affect animals.

PERTUSSIS OR WHOOPING-COUGH.

Many different organisms have been held responsible for this disease. The one now holding the field was described by Bordet and Gengou several years ago, but only cultivated artificially within the last few years. Although the discoverers failed to produce the typical disease in monkeys when using this bacillus, nevertheless they hold that the presence of agglutinin and a refined blood reaction, called complement-deviation, in the blood of patients are sufficient to convict it of being the cause of whooping-cough. They assert that endotoxins are formed. By making sections of the larynx and trachea these rods have been found lying between the delicate cilia on the free surface of the mucous membrane. It is supposed that they impede the action of these cilia and that efforts to dislodge them form the basis of the whooping paroxysm. The disease is transferred directly from one patient to another by means of spray from coughing, spitting, or talking. The rod grows only at body temperature in the presence of blood or its coloring matter. It is very like the *Bacillus influenzæ* in size and shape. It is found in the sputum early in the disease as a small ovoid polar staining rod, arranged in pairs end

to end. It is stained easily. It does not produce the disease in animals. Sputum should be received in 5 per cent. carbolic acid, and cloths used to wipe the mouth should be soaked in the same solution.

No antiserum of any value has been devised, but some observers report encouragingly upon vaccine treatment.

CHAPTER X.

THE MORE CHRONIC INFECTIOUS DISEASES.

THE diseases which have been discussed are the most important acute infectious diseases, and now those which are accustomed to follow a more prolonged course must be considered. It should be emphasized, however, that any one of these may assume a rapid or fulminating character and run its course quite as rapidly as the acute infections. These chronic infections, particularly tuberculosis and syphilis, are perhaps the most wide-spread of diseases.

BACTERIUM TUBERCULOSIS.

Tuberculosis is an infectious disease capable of attacking any organ or structure in the body, although its commonest site is the lung. The organism is the *Bacterium tuberculosis* or tubercle bacillus. The organism enters the body chiefly through the mouth and nose, usually by the air, but also in food and drink. If it follow the air passages it may settle upon the nasal, buccal, pharyngeal, laryngeal, or bronchial mucous membranes. These it penetrates, and settles usually where there is lymph tissue. This it follows with the lymph flow, and finds lodgement at some point of low resistance. It may penetrate to the true lung tissue with the air current, but it probably settles in

some of the smaller air tubes, and extends into adjoining lung tissue by continuity. It may enter the lungs by following the lymph way, or it may get there from the blood stream or lymph when it has been taken into the intestines in food or drink. These bacteria can pass through a mucous membrane into the deeper tissue without leaving any inflammation at their point of entry. After having entered the tissues proper they may be carried anywhere by the lymph and probably by the blood.

Tubercles.—Having settled at a point of low resistance, they irritate the tissue rather slowly to produce a localized inflammation which is called a tubercle, a gray body about the size of a millet seed. The cells composing this little mass are very much the same as those seen in chronic local non-tuberculous inflammations, but their arrangement, particularly when combined with large cells having numerous nuclei about their edge (giant cells), is rather characteristic of the disease. Many of these tubercles spread centrifugally and coalesce. The centre of the tubercles, being devoid of nutriment, since the blood supply is cut off, undergoes cheese-like or caseous softening. The combination of many tubercles and their destroyed centre produces large caseous abscesses. When these are in the lungs the softened centres may be removed by being coughed up after the process has ulcerated into an air passage. In the kidney the same general thing may occur, and the softened matter goes into the urine.

Forms of Tuberculosis.—When the process ulcerates into the blood supply there may result a rapid dissemi-

nation of the bacteria throughout the body, with the production of innumerable miliary tubercles everywhere. Among the special forms of tuberculosis are meningitis, hip disease, and spine (Pott's) disease. The first is a long-standing inflammation in which the cover-

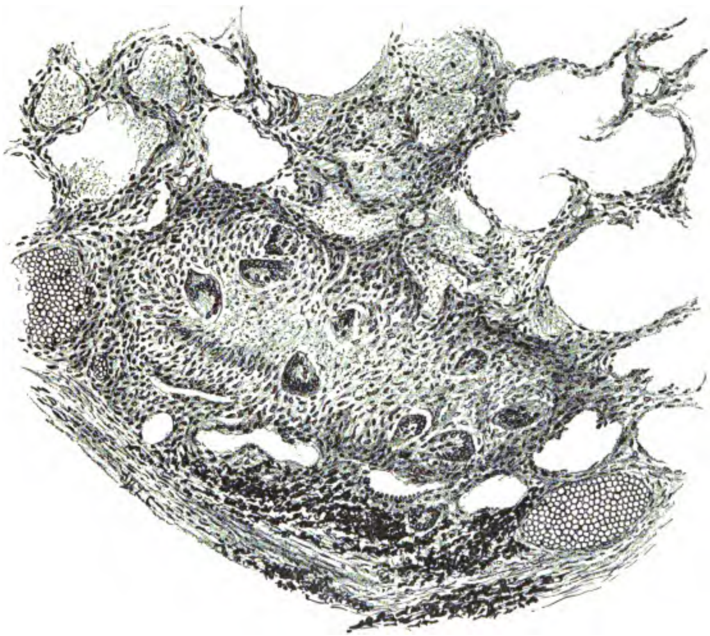


FIG. 42.—Tuberculosis of the lung. (Stengel.)

ings of the brain and cord and the superficial layers of these organs are involved in an extensive inflammation. The hip and spine diseases arise when the bacteria get into the soft marrow of the bones, and extend to the joint and tissues about it.

Toxins.—The peculiar evidences of tuberculosis are due to the toxins elaborated by the causative germ, which are both extracellular and endotoxic. The former produce the constitutional symptoms of fever and general depression of health. They are also probably responsible for some of the inflammation in the neighborhood of tubercles. The endotoxins, on the other hand, produce the peculiar local inflammation called the tubercle, and cause its degeneration into caseous material. During an infection with tuberculosis there will be developed in the body fluids a very slight amount of substance as antibody to these endo- and extracellular poisons. It is of little importance in the diagnosis, treatment, or protection of the individual, and a specific resistance to tuberculosis is not acquired by passing through an attack. Recovery ensues when the health of the individual and his tissues is strong enough to inhibit the multiplication of bacilli. A lighting up of the disease may occur when the resistance weakens by reason of some acute disease, bad habits, and the like.

Predisposing Causes and Transmission.—Tuberculosis spares no walk of life, but is more common where the lack of body care reduces resistance. It is preëminently the disease of crowded, dark, illy ventilated, badly drained tenements. It comes in the pulmonary form frequently, as an infection on top of an acute cold. The disease is spread in by far the largest percentage of cases by the direct inhalation of germs coughed out by a tuberculous person and contained in dust contaminated by tuberculous sputum. The sputum must, of course, dry before it is pulverized into dust by walk-

ing on it or sweeping it. The dust arising from soiled handkerchiefs or cloths is likewise a danger. Park says that as many as 5,000,000,000 tubercle bacilli may be expectorated by a consumptive person in twenty-four hours. Since the ordinary uneducated consumptive is very careless of his expectoration, the danger is obvious. The great movement against the "white plague," now active throughout the world, is rapidly correcting the habits of careless patients.

Tuberculosis may also be transmitted by the infection of food in the soiled hands of patients, or flies may feed upon sputum and carry the germs upon their body. The study of the transmission of tuberculosis from the cow to the human being has now progressed to a point near solution. Koch said that the bovine bacillus is not infective for the human being. This is true for tuberculosis of the lungs, but children *are* susceptible to the bovine form, which can produce in them tuberculosis of the glands of the neck and abdominal cavity, and of the meninges. Cows may give off tubercle bacilli in their milk even when there is very slight evidence of the disease in their body Milk, unless it is known to come from a non-tuberculous cow, should not be used.

The tubercle bacillus may be eliminated from the human body by the feces, and health authorities are requiring the disinfection of sewage from sanatoria. Tuberculosis is very rarely hereditary, but children born of tuberculous parents are not quite as robust as children born of non-tuberculous persons, and therefore they more easily contract the disease from the surroundings contaminated by ill parents.

Disinfection.—To disinfect material from the tuberculous individual it is necessary to collect it in some manner, permitting burning or the action of chemicals over a long time. Tuberculous sputum is best received in cardboard boxes inclosed in a tin cup. The boxes are burned, and the tin cup washed in 5 per cent. carbolic acid at frequent intervals. If the person expectorate into cloths they should be burned or soaked in 5 per cent. carbolic acid for at least six hours. If neither of these methods is used expectoration should be received in a bowl or pot containing 5 per cent. carbolic acid or lime solution. Feces and urine should be received and well mixed into the same solutions. After death from tuberculosis the room and all contents should be disinfected with formaldehyde gas.

Diagnosis.—The most important means of diagnosis is by finding the tubercle bacillus. To do this, the sputum, urine, feces, pus, exudate, or a piece of tissue is taken, stained by special methods, or injected into guinea-pigs. The material to be examined is spread on glass slides and stained by a special technic. The tubercle bacillus, because of the presence of waxy and fatty matters in it, stains with difficulty and when once stained cannot be decolorized by acid or alcohol, for this reason being called an acid-fast organism. In order to stain the rod it is customary to use a chemical, called a mordant, to assist the staining material in penetrating; these mordants are usually carbolic acid and anilin oil. The dye is usually fuchsin, imparting a red color to the organisms. After staining, a decolorizing solution is applied to the preparation and all but the tubercle bacilli are destained, leaving

rėd bacilli, which are easily distinguished under the microscope.

Sometimes the germs are present, but cannot be found by staining. Some of the material is then introduced under the skin or into the peritoneal cavity of guinea-pigs. If tubercle bacilli be present, evidences of the disease will appear in these animals in from two to five weeks. The bacilli can be found by staining smears from the tubercles. Agglutinins are formed in tuberculosis, but the clumping test is of little value.

The *tuberculin reaction* is a very important diagnostic measure. During its growth on artificial media in the laboratory, the tubercle bacillus develops its endo- and extracellular toxins. If these poisons, called "tuberculin," obtained by removing the living organisms from a fluid culture, be injected under or rubbed into the skin, a characteristic reaction occurs. The subcutaneous injection of as small a quantity as 5 milligrams or about $\frac{1}{16}$ minim of Koch's tuberculin will cause a definite rise of temperature and a feeling of general malaise within twenty-four hours. There is besides this a congestion of the tuberculous process in the lung or wherever it may be. The inunction of a drop of this solution into the skin, combined with a slight irritation of the surface, will cause a reddened papule or even a vesicle upon a swollen base to appear within twenty-four hours. There are several modifications of this skin test in practice, but the principle is the same in all. Tuberculin, purified by precipitation with aclohol, can be obtained in a powder form, a solution of which has the property of calling forth a

reaction in a tuberculous person. This refined product is used in the conjunctival test by dropping a small quantity into the eye. If tuberculosis be present a congestion and discharge will appear in the conjunctiva within forty-eight hours.

It is claimed by many that all adults have some tuberculosis in their body, acquired during childhood, which has remained quiet or has healed completely, but which has left their blood in such a condition that a tuberculin reaction will appear. For this reason the skin test may be positive in adults who are really not suffering from their slight latent infection, and it is therefore not reliable. It should only be used in children. The supposed cause of the tuberculin test either under or upon the skin, is the stimulation of the tuberculous disease by the introduced toxin, and the outpouring from the tubercles of more of their own poison. No reaction of any sort follows the administration of tuberculin to persons free from tuberculosis.

Morphology and General Characteristics.—The tubercle bacillus is a true parasite, that is, it does not multiply in nature outside the animal body. It is a rather large organism, about $\frac{1}{70000}$ inch wide and from $\frac{1}{20000}$ to $\frac{1}{5000}$ inch long. It may be straight or slightly bent, usually single, but also in pairs. It is non-motile, and produces no spores. It stains with considerable difficulty, owing to its thick cell wall. There is much fatty and waxy matter in the tubercle bacillus which gives it its resistant power. It grows upon laboratory culture media very slowly. For this reason it must be obtained in as pure a condition as possible. Cultures are best made from the lesions in guinea-

pigs. For its growth this organism requires the addition of glycerin, blood serum, or egg to the ordinary nutrient broths and jellies. It will grow only at body temperature, and not at room temperature.

It is killed by an exposure to 60° C. or 142° F. in thirty minutes, to 70° C. or 160° F. in ten minutes, and at 95° C. or 200° F. in one minute in watery suspension. Dry heat at 100° C. or 212° F. requires about one hour. The organisms resist drying in the dark for considerable periods. Direct sunlight kills them if in thin layer or small clumps within four hours. Diffused light requires two weeks for their destruction. Sputum protected from direct sunlight may contain living bacilli possibly for one year. Five per cent. carbolic acid should certainly kill them in sputum in twelve hours; in watery suspension in thirty minutes. *Bichloride of mercury* is *not* of value for *sputum* disinfection, but in strength of 1 to 1000 in watery suspension is fatal in one hour. No kind of animal is absolutely resistant to tuberculosis, but there are some that very seldom present the spontaneous disease, notably dogs and horses.

There are four forms or varieties of the tubercle bacillus: the human, bovine or cow, bird, and reptilian. The first two only concern us, and the distinguishing features of these groups are of small importance here. The infectiousness of the bovine form for humans has been mentioned. The human form is of very low virulence for the cow, but may infect most of the smaller animals. It has been found impossible to obtain from any of the lower animals a serum which will have a beneficial effect upon the disease in human

beings. That is, no serum can be procured which will give a passive immunity.

Tuberculin.—The poisons made in cultures and used for the tuberculin test in the form of Koch's tuberculin have already been mentioned. There are many forms of tuberculin which are incidentally modelled after Koch's plans. His original was a broth upon which the bacteria had grown, but freed of living forms and reduced by evaporation to one-tenth its original volume. This contained both the endo- and extracellular toxins. His later forms consisted of killed bacteria, of a watery extract from them and lastly, living bacteria so reduced in virulence that they could not produce tuberculosis. These are all tuberculins, the last forms being called vaccines also. Not only are these toxic solutions of value for diagnosticating tuberculosis, but they may also be used in treatment, the purpose being to induce some active immunity to the tubercle bacillus poisons. They are injected under the skin of tuberculous patients, beginning with extremely minute doses, too small to produce the tuberculin reaction described above. We increase the quantity gradually until the patient can endure large amounts. It is maintained that this treatment is very beneficial and that a slight immunity is achieved. Opinions vary as to its value, but those who have had longest experience usually testify to its efficacy, although no one maintains that it is a cure-all, but merely another means of treating this serious disease. This is in reality an active immunization during the course of the disease, but it has not been found possible to inject a healthy person in the same manner and thereby increase his resistance to tuberculosis.

TREPONEMA PALLIDUM.

Syphilis is one of the venereal diseases. It is chiefly acquired by cohabitation, but may also be contracted by nurses and physicians in their professional relations with patients. It is a chronic infectious disease characterized by three stages, the first a primary, acute, active, self-limited ulceration, with some regional lymph-gland swellings; second, a period in which various eruptions appear on the skin and mucous membranes (mucous patches) with slowly progressive changes in some of the internal organs, and third, a last stage of soft tumor formation (gumma), with fibrous affections of the organs and degenerations of the nervous system.

It is caused by a spiral organism called the *Spirocheta pallida* or *Treponema pallidum.* This bacterium enters small cracks or wounds, penetrates to the deeper layers, invades the lymph channels, and produces the primary sore, the hard chancre. Even before this is fully developed, the spirochetæ have journeyed to the neighboring lymph glands, where an enlargement results. They then invade both the lymph routes and the blood and rapidly infest all bodily tissues. They stimulate the small round cells of blood and tissue to multiply even up to fibrous tissue formation, and they cause degeneration of the functionating structures. Just how they make the gumma is only conjectured. All their effects, however, are probably due to the toxins set free upon their death and disintegration. The spirochetæ remain in the body as long as the patient lives, if untreated. They leave the

patient probably only with the moisture of ulcerated surfaces, and one protects against contamination by covering the ulcerated surfaces or wearing hand protection. The mildest of antiseptics will destroy the germs. The incubation period varies from four weeks to as many months.

Forms of Syphilis.—This frightful disease which causes so much mental and physical suffering may be hereditary, congenital, or acquired. The course of the three types varies a little, but the ultimate effect is the same in all. In the first there are evidences of imperfect physical and mental development; the second is an active form of the disease with symptoms and infectious catarrhs and is easily transmitted to attendants: the third is the form described above.

Transmission.—Aside from cohabitation, syphilis may be transmitted by kissing, examining a patient, or using any object that has come in contact with an open sore. Wet-nurses may contract it from infected children and transmit it to healthy children whom they nurse. Both may be protected if those in charge will have a Wassermann test made. If the child be syphilitic it should be raised on the bottle, while a wet-nurse with the disease would better never nurse other than her own child. In protecting against infection a weak (1 to 2000) bichloride of mercury solution should always be on hand that the ulcers may be wiped before examination and the hands disinfected afterward. That occupying a bed with an actively diseased syphilitic or using anything belonging to him must be avoided goes without saying.

Diagnosis.—In the serum of a syphilitic certain antibodies are formed that can be made use of in diagnosis. This is the basis of the Wassermann test upon the blood, due to antibodies like bacteriolysins. Its theory and practice are too intricately technical to be included here. Suffice it to say that it is certainly a positive test in 95 per cent. of cases in which there exists untreated syphilis. Proper treatment destroys the Wassermann reaction, but whenever it results positively some form of syphilis is present, although it may not be in a form transmissible to others. Otherwise syphilis is diagnosticated by finding spirochetes in the serum which exudes from chancres, skin eruptions, and mucous patches, or the venereal warts on mucous membranes. This serum is taken and looked at unstained upon a background of India ink or by what is called dark-field illumination, a process by which the light is made to shine upon the body of the spiral from the side. It can also be stained by appropriate methods, but its minute size and paleness make this a trying test.

Morphology and General Characteristics.—The *Spirocheta pallida* is a corkscrew-like, actively motile, delicate thread. Its windings assume the form of a large arc of a small circle, and vary from four to twenty. It is $\frac{1}{100000}$ to $\frac{1}{75000}$ inch wide and from $\frac{1}{8000}$ to $\frac{1}{1000}$ inch long. It moves by end flagella, in a screwing and waving motion. It is killed rapidly by drying, a very fortunate thing, as many people are thereby protected. Against weak bichloride and carbolic acid it has no resistance. Alcohol will destroy it in five minutes. Up until the beginning of 1911 no success had met attempts to cultivate these spirals

in the laboratory. Noguchi finally succeeded in growing them under anaërobic conditions in a mixture of serum and agar to which a piece of sterile liver or kidney of rabbit had been added. Only rabbits and monkeys among the lower animals can be made to contract syphilis, but of these only the latter shows any similarity to man in the course of the disease.

FIG. 43.—Treponema pallidum appearing as bright refractive body on a dark field, as shown by India ink or ultramicroscope. (Park.)

When infective crusts from eruptions or serum exuding from them is kept in the test-tube for six hours, infection can no longer be transferred to monkeys. No serum of therapeutic value has as yet been produced, nor can immunity be induced by injecting dead spirochetes. A remedy, salvarsan, consisting of a complex arsenical compound, has been found to cure syphilis. It is efficacious at all stages, stopping

and curing the disease if given at the time of chancre, and materially improving the nervous condition of the late stages. Lately Noguchi has made an extract of spirochete bodies which can be used as a skin test for syphilis precisely as tuberculin is rubbed into the skin in diagnosis of tuberculosis. He claims good results during the later stages, but as a diagnostic test of recent infection it has not yet proven of value.

Chancroid.—There is a venereal disease known as *chancroid* or *soft chancre* in contradistinction to the primary hard chancre of syphilis. This is an acute infectious condition due to the bacillus of Ducrey. The lesion begins as a pustule, which soon breaks down into a spreading ulcer. The disease is communicated by direct contact usually. The bacilli are in the discharges and therefore can be transferred through the intervention of dressings. The bacilli are extremely small, double rods, not motile, and form no spores. These grow on laboratory media containing blood. They do not possess a great viability under artificial conditions, and therefore are destroyed in discharges quite easily. Simple drying seems to kill them shortly, and weak solutions of the ordinary disinfectants are quickly efficient. We assist in the clinical diagnosis of chancroid by finding the diplo-rods, mostly within leukocytes, in scrapings from the depth of the ulceration.

RELAPSING FEVER.

Relapsing fever is caused by spirochetes whose species differ in the various countries, Europe, Africa, India, and America. The transmission is only known

for the African variety, which spreads by means of a tick. The spirochete circulates in the blood during attacks and settles in the spleen between them. The disease is characterized by intermittent attacks of continued fever beginning suddenly, lasting four to six days, and ending by crisis. The febrile periods recur with eight to ten days intervals of freedom from symptoms. Blood is examined during the fever and we find under the microscope long, $\frac{1}{5000}$ inch,

Fig. 44.—Spirochæta Obermeieri blood smear. Fuchsin. × 1000 diameters. (From Itzerott and Neimann.)

delicate, $\frac{1}{50000}$ inch wide, wavy spirals with corkscrew and undulatory movements.

The spirochetes have been cultivated, under anaërobic conditions, in serum supplied with fresh animal tissue and these cultures may be transferred to monkeys and mice. Some immunity is left after an attack, and use has been made of the serum in treating the sick. As there are several species of this spirochete, differing very slightly, and to make an antiserum it is necessary to use many varieties.

BACTERIUM LEPRÆ.

Leprosy is a chronic endemic infectious disease characterized by the development, in the skin chiefly, but also the mucous membranes, of firm nodules and diffuse swellings due to the growth and irritation of the *Bacterium lepræ* or leprosy bacillus.

Forms of Leprosy.—There are two forms, the nodular and anesthetic. The former is usually painless throughout its course, merely giving rise to the cutaneous nodules. The anesthetic form is due to an involvement of the sensory nerves, which are at first irritated with the production of a painful early stage, followed by destruction of sensation when the inflammation has progressed further. The disease gives rise to considerable superficial destruction of tissue, which is responsible for the horrible pictures of this disease in the lay mind. Fingers, toes, nose, and pieces of skin may be removed by ulceration. The disease is an old and wide-spread one, commonest in the tropics, but by no means confined to them. Despite long familiarity with leprosy, there are many points as yet undecided about its nature.

Transmission.—The bacteria probably enter by the nose and mouth, and it requires close association with a leper for a long time in order to contract the disease. It seems that it may be hereditary in the sense that parent and child may be infected. It is much more probable that the child is born free of disease and acquires it by association with the parent. The low contagiousness of leprosy should be emphasized. If one should say in a crowd, "There is a leper!" the

people would shun him as if he were a maniac with a firearm. If one were to say under similar conditions, "There is a consumptive!" he would be pitied and perhaps not avoided at all. Tuberculosis is vastly more easily transmitted than leprosy. The inhuman treatment accorded to lepers is due to this misapprehension.

Fig. 45.—Schematic representation of section through a lepra nodule: left side of picture gives appearance under low magnifying power; right side, the appearance when highly magnified. In the latter the large lepra cells are diagrammatically indicated. (Abbott.)

When the bacteria enter the mucous surfaces they are carried by the lymph or blood to the exposed skin surfaces, chiefly the face and hands. Here they settle in the subcutaneous tissues and nerves, producing a chronic inflammation in which *lepra cells* are found. These are large round or oval cells, crowded with bacilli, lying irregularly throughout the inflammatory tissues. Leprosy does not form definite tubercles like tuberculosis, but the process is more diffuse; nor

does caseation occur. Giant cells are uncommon. The bacilli produce these changes largely by poison in their body and by mechanical irritation. There is some reason to believe, by most recent researches, that a soluble or extracellular poison is formed. The bacteria are discharged from the patient by the sloughing of wounds, especially the ulcers in the nose and throat. The dressings and cloths used to wipe the nose should be burned. Intimate contact, such as sleeping with or kissing lepers, should be avoided, but there is no proof that ordinary relations of human life easily transmit the disease. The best diagnosis is made by finding the rods in their peculiar cells, which is best achieved by removing a piece of the skin growths.

Morphology and General Character.—The leprosy bacillus, like the tubercle bacillus, is stained with difficulty, and belongs to what are called the acid-fast bacteria. Methods similar to that described for the tubercle bacillus must be used, but the determination is by no means simple even to the most experienced bacteriologists. The similarity to the tubercle bacillus is further shown by the fact that the tuberculin skin test is positive in lepers. A poison similar to tuberculin, called leprin, has been made by extracting leprous tissue. It is only within the last five years that the pure direct cultivation of *Bacterium lepræ* has been successful, and then only upon special media with a very delicate technic. More about the poisons will probably be learned in the near future. The bacillus of leprosy is a straight rod with rounded ends, a trifle smaller than the tubercle bacillus. Its resistance to chemicals and heat is probably the

same as that organism. It grows only at body temperature. Some attempts have been made to use devitalized leprous tissue and the vaccines from the tubercle bacilli as a remedy. These have met with indifferent success.

Acid-fast Bacteria.—The two organisms of tuberculosis and leprosy are members of the acid-fast group. There are numerous other bacteria that stain and are decolorized with difficulty, but these are the important disease producers. Such an organism, called the *Bacterium smegmatis*, exists normally in the smegma about the genitals, and is often a source of confusion when examining for tuberculosis of the urogenital apparatus. It does not produce disease, however. It is possible also to exclude it by a special staining method. Other acid-fast bacteria exist in manure, hay, and butter.

BACTERIUM MALLEI.

Glanders is chiefly a disease of horses, characterized by nodular growths and ulcers in the upper air passages or diffuse swellings under the skin. In the latter form it is called farcy. The causative organism is the *Bacterium mallei* or glanders bacillus. Human beings, who are associated with horses or who work in the laboratory with cultures, may contract the disease, usually, however, in the acute form, whereas the lower animals commonly have a protracted attack. The bacteria enter by small cracks or wounds in the mucous membrane of the mouth or nose, and are carried by the lymph or blood to subcutaneous tissues. Whether

they produce glanders proper or farcy, they stimulate the tissues to produce nodules not unlike the tubercle, but of more rapid progression. Quite early they break down into abscesses or through the skin as large sloughing ulcers. The poisons are almost entirely endotoxins, and may be extracted from cultures. A slight amount of resistance is gained by passing through an attack.

Diagnosis.—Agglutinins are formed in the blood and the clumping test is a valuable means of diagnosis. The bacteria may also be found by making smears and cultures from open ulcers or by withdrawing some of the pus from an abscess. This pus may be injected into the peritoneal cavity of a guinea-pig, obtaining as evidence of the presence of the *Bacterium mallei* an inflammation of the testis. The most practical method of diagnosticating glanders is by the use of the mallein test. Mallein is the poison elaborated by the *Bacterium mallei* in laboratory cultures. It is comparable to tuberculin, and may be used like it, by injecting it under or by rubbing it upon the skin. Reactions of temperature and reddening of the skin indicate the presence of glanders. The bacilli may be found also in stained smears of the pus lying in pairs on end within the large so-called epithelioid cells. Blood cultures sometimes give a growth. The disinfection of human material should consist in burning all dressings from ulcers or cloths used to wipe the nose or mouth. Bacteria leave the body only with the purulent discharges. Strong antiseptics, such as 1 per cent. carbolic acid, should be used for the hands and objects possibly soiled by discharges. Glanders

is a very infectious disease, and the bacilli are pertinacious.

Morphology and General Characteristics.—The glanders bacilli are straight or slightly curved rods, usually single, but also in pairs or short filaments, and measure from $\frac{1}{20000}$ to $\frac{1}{5000}$ inch in length and from $\frac{1}{100000}$ to $\frac{1}{50000}$ inch in width. They stain with reasonable ease. They grow at 37° C. or 98° F. very much better

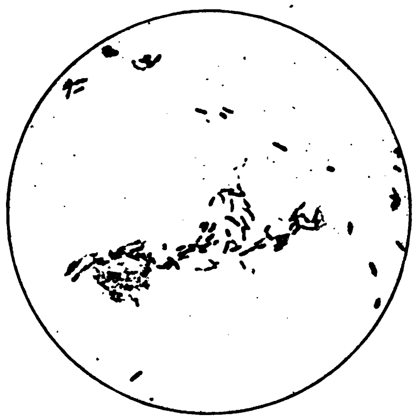


FIG. 46.—Glanders bacilli. Agar culture. × 1100 diameters. (Park.)

in the presence of oxygen than in its absence. They do not form spores nor are they motile. They are killed at 55° C. or 130° F. in ten minutes; by 1 to 1000 bichloride or 1 to 100 carbolic acid in ten minutes. After drying they may live for ten days, but do not live long in nature outside the animal body. They are easily grown upon most of the laboratory foodstuffs. Most of the lower animals are susceptible to glanders and it is of some importance in menageries.

The disease in animals is like that described for persons, and the beasts do not develop anything in their blood which can be used to treat human beings. Vaccines are not successful probably because the disease in people is too acute to be amenable to a treatment with mallein comparable to that described for tuberculin.

BACTERIUM ANTHRACIS.

Anthrax, or woolsorters' disease, or splenic fever, is chiefly an acute infectious disease of animals caused by the *Bacterium anthracis* or anthrax bacillus. It is contracted by human beings through association with infected animals, hides, wool, rags, and the like. It is not uncommonly fatal to persons. It is expressed as superficial abscesses, pustules, or carbuncles scattered over the skin, or as softening of the spleen, hemorrhages into the intestinal wall and some other of the organs, even the brain. The woolsorters' disease, or pulmonary form, occurs from inhaling bacilli into the lungs. The bacteria also enter by swallowing, or by wounds and cracks. However they enter they spread by contiguity or by the lymph. Their chief action is local and they do not enter the blood stream except near death. They do not settle in one place and remain there, but may pass from one localization to another. While most of the noxious effect is mechanical the anthrax bacillus seems to produce a little extracellular toxin which has the power to attack tissue and cause the accumulation of edema and blood. The softenings are due to the killing effect of the bacillus poisons upon the tissues. This solvent

action also attacks the walls of bloodvessels permitting the leaking of blood or a true hemorrhage. The poisons are further absorbed by the circulation with a resulting fever and general illness. The bacteria may leave the body with pus or sloughs, by the expectoration in the pulmonary form, or by the feces when the infection is intestinal or has become generalized.

Protection against anthrax is secured with difficulty since its organisms produce resistant spores. The sputum, feces, and wound discharges should be so received that immediate burning is possible. Chemical disinfection is much less reliable. Five per cent. carbolic acid should be allowed to remain in contact with infective material for two days. Corrosive sublimate, 1 to 1000, for one day is usually sufficient.

Anthrax is diagnosticated by finding the bacteria, not a very difficult matter since they grow with comparative luxuriance on laboratory media. Smears also assist because of the characteristic appearance of the rods.

Morphology and General Characteristics.—The anthrax bacillus is a large straight rod with sharply cut ends. It measures $\frac{1}{15000}$ to $\frac{1}{2000}$ inch long by $\frac{1}{25000}$ to $\frac{1}{20000}$ inch wide. It does not possess motility, but does form round, oval, or elliptical spores, situated near the centre of the rod. The bacilli may grow in chains suggesting bamboo sticks. They require oxygen. The rods but not the spores are easy to stain. There is a delicate capsule about the organisms when stained in pus. They grow best at 37° C. or 98° F., but also at lower temperatures. The vegetative rods are killed

at 54° C. or 130° F. in ten minutes; the spores are killed by boiling ten minutes or in dry heat at 140° C. or 285° F. for ten minutes. The resistance to chemical agents has been considered on page 57. It is best not to rely on any chemical killing of anthrax spores, as different cultures vary in resistance and the environment plays an important part. Anthrax bacilli grow well and characteristically on laboratory culture media. It is not possible to produce a passive immunity to anthrax, but among the great achievements of Pasteur

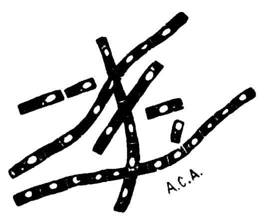


FIG. 47.—Threads of Bacterium anthracis containing spores. × about 1200 diameters. (Abbott.)

was the discovery of a method of rendering sheep actively immune to anthrax. He discovered that by growing anthrax bacilli at a temperature of 42° C. or 106° F. instead of 37° C. or 98° F. he was able to reduce their virulence considerably. By varying the length of time of cultivation at this temperature two different strengths were obtained. He now injected the weaker, and followed a few days later with the more virulent. The resistance of the animal can thus be raised to a high level for about a year. The method is not practicable for human beings.

ACTINOMYCOSIS.

Actinomycosis or lumpy jaw is chiefly a disease of animals, but may affect man. It is characterized by the production of large semisolid tumefactions usually in the upper air passages or their neighboring tissues and in the lungs. It may spread under the skin or into organs. The bones of the jaw are usually involved. Any bone in the path of progression of the disease may be infiltrated. The organisms causing it belong to the higher bacteria, and are called *Streptothrix actinomyces* or ray fungus, because of their tendency to spread out in rays. The organism enters by way of the mouth or nose into cracks or wounds. Association with animals having the disease is the method of infection in man.

When the germs enter they start to proliferate and excite a nodule not unlike that of tuberculosis. It spreads by continuity outward and involves adjoining structures. The centre of the nodules softens into caseous matter in which small white or gray masses of the bacterial growth may be found. This is the chief source of material by which the diagnosis is made. The large tumors ulcerate through the skin at times and present sloughing areas. This is the manner also in which the infecting germ leaves the body. In diagnosticating the disease one of the small granules in the pus is taken, crushed beneath a glass, and examined directly under the microscope for the ray fungus. The specimen may also be stained.

Infective material from abscesses or ulcers or the sputum should be burned. Chemical destruction is

less reliable. Ordinary care of the hands will suffice as a protection, but no lack of care is justifiable. It is not a very infectious disease, but a serious one and one of long duration. The peculiar changes in this disease are due to the life and growth of the fungus as a foreign body and probably not to any peculiar toxin. No immunity or peculiar blood changes follow an

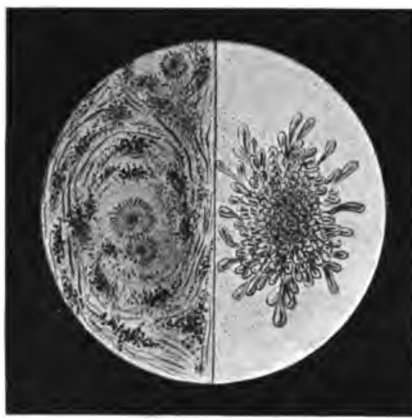


FIG. 48.—Actinomyces fungus ("ray fungus"): left, as seen in tissues under low magnifying power; right, a fungus mass examined fresh under higher magnifying power. (Abbott.)

attack. The treatment is surgical and medical, the latter being confined to the use of potassium iodide.

Morphology and General Characteristics.—The organism of actinomycosis is in the form of interwoven threads, radiating from a centre, having thickened or bulbous ends. These ends are important, as they assist in species determination and possibly have something to do with multiplication of the germ. The

threads are about $\frac{1}{75000}$ to $\frac{1}{50000}$ inch wide, their length being very variable. The bulbs measure from $\frac{1}{60000}$ to $\frac{1}{30000}$ inch in width and vary in length. They grow with reasonable freedom in the laboratory, especially upon media containing animal substances such as blood serum. Their optimum temperature is 40° C. or 102° F. They are killed at 75° C. or 167° F. exposed ten minutes. They resist drying for a long time. They are extremely resistant to chemical disinfectants. Not all animals are susceptible to actinomycosis, but those contracting it present about the same type of lesions. Nothing in their blood serum is of any value in treatment of human beings. Vaccines are not used.

CHAPTER XI.

VARIOUS PATHOGENIC BACTERIA NOT ASSOCIATED WITH A SPECIFIC CLINICAL DISEASE.

THERE is a large class of bacteria capable of producing various inflammations or infections that do not follow a constant or even uniform course. Surgically speaking, they are probably the most important group aside from the pus cocci. It is not possible to make many generalizations concerning these organisms. The results of infection with them vary greatly, depending first upon their own virulence and second upon the resistance of their host. Biologically, many of these non-specific germs bear a close relationship to species giving a very definite clinical disease. In the first example, the colon bacillus, this is well illustrated. A certain group of bacteria is spoken of as the typho-colon series. This means that they possess characteristics relating them to one another. Certain members of the series can be separated only by very careful technic, yet they are capable of setting up easily distinguishable affections.

THE TYPHOCOLON BACILLI.

The colon bacillus is the common normal inhabitant of animal intestines, particularly of the colon, whence it

derives its name. The group of bacteria, the typhocolon series, to which this organism belongs and of which it and the typhoid bacillus are the most conspicuous representatives, embraces many species, subspecies, and varieties. A botanical and chemical classification satisfactory to all authorities has not yet been made. It can be said in general that all members of this group find the intestinal tract a suitable place for life, some under normal, others under pathological conditions. Old classifications of the typhocolon group admitted only organisms capable of motion, but some later observers include many non-motile, and even encapsulated forms. Inasmuch as a very close separation on the basis of technicalities is not necessary in this work, it has been deemed best to choose the principal clearly defined species for description. Such descriptions permit of extension in a general way to the nearest congeners, and therefore we may say that we are considering types. The typhoid and paratyphoid bacilli have been sufficiently described in Chapter IX.

The Colon Bacillus.—The colon bacillus proper, called also the *Bacillus coli communis*, is a non-spore-bearing, sluggishly motile, delicate rod, measuring from $\frac{1}{25000}$ to $\frac{1}{8000}$ inch in length and $\frac{1}{60000}$ to $\frac{1}{30000}$ inch in width. It appears when stained as a single rod usually, but occasionally in pairs or short chains. It takes the laboratory dyes with ease, usually more deeply near its rounded ends. It moves by flagella arranged all about the cell wall. It grows with ease artificially, best in the presence of oxygen, but also in its absence. Development will occur at any temperature from 10° to 43° C. or 50° to 108° F. It pro-

duces no spores. No color or pigment is developed when cultivated in the laboratory. It possesses the power of coagulating milk and of acid fermentation, with the production of gas, in most of the carbohydrates (sugars and starches) used for the differentiation of bacteria. It does not produce ferments capable of liquefying gelatin or the milk curd. It does, however, break up simpler substances and forms indol, a putrefactive product.

FIG. 49.—Colon bacilli. Twenty-four-hour agar culture. × 1100 diameters. (Park.)

The colon bacillus is killed at 60° C. or 140° F. in ten minutes. It resists freezing for a long time, perhaps several months. Drying usually kills in one day, but certain individuals may remain viable for many days or weeks. It is killed by carbolic acid, 1 to 1000, in twenty minutes, or 5 per cent. in two minutes in watery suspension. About the same times hold for bichloride of mercury, 1 to 4000 and 1 to 1000. To weak acids it is resistant, as is shown by its passage

in food through the hydrochloric acid of the stomach. This is also true of the typhoid bacillus. It will multiply in feebly acid or alkaline solutions. Direct sunlight kills almost at once, while diffuse light is withstood for a long time.

The colon bacillus is found in the intestines of man and animals in health or disease. It is expelled with the feces and therefore gets into water-courses. The bacilli may be found in the superficial layers of the earth. Examination of water for public health purposes aims at its discovery as an indication of sewage pollution. Its presence in milk may be accounted for by contamination of milk in cans washed with polluted water. It should not be forgotten that despite the greatest personal care, colon bacilli are widely distributed on everything that comes in contact with man and animals. The newborn baby's intestine is free of them, but does not long remain so, as the organisms find their way in with food, from the hands of attendants, or possibly through the anus and up the rectum. The colon contains most of the bacilli and the number decreases upward in the small intestine until in the stomach they are rarely found. They may, however, at times enter the liver by means of the bile passages or portal vein system.

The constancy with which the colon bacilli are present in the intestine raises the question as to their function or value there. This is probably best answered today by saying that they assist in controlling the growth of certain putrefactive bacteria, and that they may assist somewhat in breaking up simple substances so that these may be more easily absorbed.

The toxin of the colon bacillus is within its body, no extracellular poison being formed. If one inject the dead organisms into an animal in sufficient number, mucous membrane irritation, paralyses, and convulsions may occur. Living bacilli introduced into the peritoneum cause peritonitis and septicemia, the organisms entering the blood stream. An abscess will usually result if they are brought under the skin. In man colon bacilli seldom go beyond the mucous membrane of the intestine because of the resistance offered by that tissue. After death the organisms rapidly invade the different organs of the body. Whenever the resistance of the body is reduced an opportunity is presented for the spread of these organisms. When for any reason the colon bacillus gains in virulence or the resistance of the intestinal wall decreases, there arise inflammation of the mucous membrane of the intestine, a swelling of Peyer's plaques comparable to that seen in typhoid fever, and these changes permit the bacteria to spread in the body. There may arise inflammation of the gall-bladder, the pelvis of the kidney, or abscesses in various parts of the body. Cystitis may occur, which may be a part of a general infection, descend from the kidney, or arise from introduction of the organisms through the urethra. An ascending infection from the bladder to the pelvis of the kidney and on into the substance of the organ is not an uncommon disease process. This frequently occurs in pregnancy or after labor. The colon bacillus is the commonest single organism to cause pyelitis.

The inflammations of the gall-bladder and its passages and of the liver may arise either from introduction

of bacilli up the common bile duct, or as a part of colon bacillus septicemia. The peritonitis seen after perforation of the intestines is the result of many kinds of bacteria of which the colon bacillus may be the most numerous. It is probable that this organism alone is able to inflame the peritoneum, as it certainly can produce localized and diffuse pus collections. The colon bacillus is frequently the only organism found in acute appendicitis. It has been found as an important factor if not the sole cause in pneumonia and pleurisy. It has been found to cause meningitis and endocarditis.

No antiserum of practical value has been produced by the injection of these organisms into the lower animals. On the other hand, some success has been attained in establishing active immunity both as a preventive and as a remedial agency by injecting increasing quantities of dead bacteria.

Diagnosis.—Colon infections are diagnosticated chiefly by finding the organism. They are present in the fibrinous exudate or pus, and in the blood in septicemia. We grow some of this in ordinary nutrient broth or jelly, and isolate in pure culture. Colon bacilli are, of course, easily obtained from the stools. The agglutination or clumping test can also be used in colon bacillus infections, since agglutinins are formed during an attack. Pus or other bacteria-containing substance should be disinfected by mixing with 5 per cent. carbolic acid and allowing it to act for at least one-half hour.

Paracolon Bacilli.—These organisms resemble the *Bacillus coli communis* so closely that only the dif-

ferences need be noted. They are more actively motile, they do not coagulate milk but probably produce alkalinity in it; they are capable of producing acid and gas in only three of the sugars. They differ from the paratyphoid bacilli in their action upon milk and their greater ability to ferment the carbohydrates. These two groups, the paracolons and paratyphoids (see page 127), are called the intermediates between the true typhoids and colons. Their cultivation is performed as outlined for the colon bacillus. The typical species of this group is the *Bacillus enteritidis* of Gärtner or the meat-poisoning organism.

The disease produced by this bacterium is usually very acute, but in infections by some members of this group the disease may last nearly as long as paratyphoid fever. The bacteria are present in meat, probably within the animal before slaughter. In Europe where the refrigerating systems are less complete than in this country, meat passes from the butcher to the consumer directly, and therefore there may be epidemics when infected cattle are slaughtered.

The bacteria pass into the intestines, are absorbed by their walls, and pass into the blood stream. The infection gives diarrhea of the typhoid or cholera type, prostration, and sometimes delirium. The disease is usually transmitted only by meat in the form of cuts or as sausage, and these foods are unaltered in color and taste by the presence of the bacteria.

The toxin is peculiar in that it resists cooking sufficient to destroy the life of the bacilli and drying or smoking does not diminish its power. It is an endotoxin. The bacillus may form pus, and the author

has seen it as the cause of a diffuse pelvic inflammation. When injected into animals the paracolon bacilli are capable of giving rise to a fatal septicemia with acute inflammations, hemorrhages, and collapse. The bacilli are found chiefly by examination of the stools or by cultivation of the circulating blood or material from abscesses. Infective material should be rendered innocuous by the means outlined for the colon and typhoid bacilli (p. 125).

A very important means of diagnosis with all the infections of the typhocolon group is the agglutination test. These congeners produce agglutinins having some affinity for all members of the group. The method of use in this test consists in finding that member of the group that will be clumped by the greatest dilution of the patient's serum. This organism is then considered the causative one. No practical remedy has been found by the use of antitoxins or vaccines.

MUCOSUS CAPSULATUS GROUP.

This group has been included with the colons by many of the later writers. Such a classification is open to some objection, but it is quite proper to discuss the organisms directly after the colon group, since the two types have some things in common and both are constantly present in the intestinal tract.

The bacteria in question are non-motile, plump, straight rods without spores, but surrounded by a capsule, at least when in the animal body. They measure from $\frac{1}{35000}$ to $\frac{1}{5000}$ inch in length and from $\frac{1}{50000}$ to $\frac{1}{16000}$ inch in width. They may be found

lying singly, but when in the body are commonly united in pairs or short chains about which one may find the capsule. We may find the capsule in milk or gelatin cultures. They are easily stained by ordinary dyes. They grow well, best at body temperature, but also as low as 12° C. or 54° F., or as high as 41° C. or 106° F. They are killed at 56° C. or 133° F. in ten minutes. They resist drying quite well. Freezing is rather rapidly fatal to them. They grow best in the presence of oxygen, but may live without it. All the artificial cultivations of this group are characterized by luxuriance, with a tendency to a slimy, smeary, or tenacious consistency, hence the name "mucosus." None of the group can soften gelatin or make indol. They all produce some degree of acidity in milk, but not all can curdle it. The various members behave very differently in regard to sugars, and upon these reactions they are classified.

The poison produced by the bacteria of this group is probably all endotoxic. They irritate the part also mechanically by their presence. These bacilli are widely distributed in animal life, but less so otherwise in nature. They are transmitted directly from man to man, by particles of saliva or sputum or in fecal discharges, or in pus; which should be disinfected as given for the colon bacillus. Besides the special conditions to be mentioned later, members of this group have been known to cause pyelitis, gastro-enteritis, peritonitis, pleuritis, and septicemia.

The most important member of the group is the *Bacterium pneumoniæ* of Friedländer, a cause of pneumonia next to the pneumococcus in importance

for the acute lobar form. The pneumonia is characterized by its sticky nature. It is usually short in duration and grave in prognosis. The bacilli may enter the circulation and give rise to localized inflammations, including abscesses, elsewhere in the body.

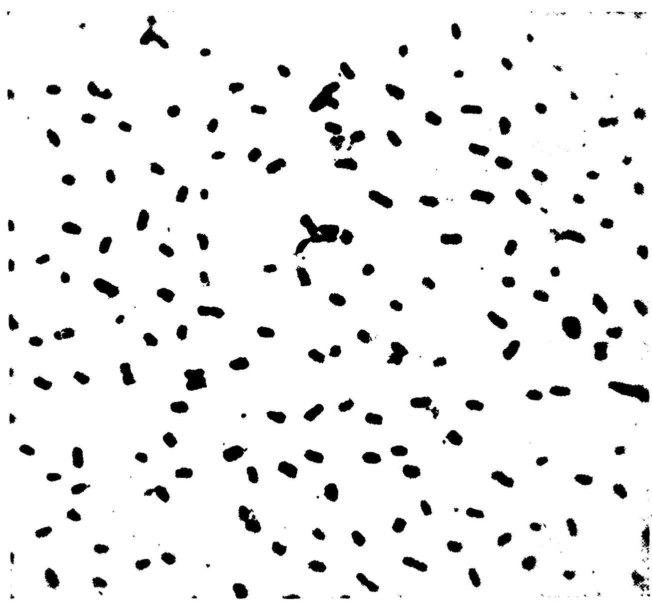


FIG. 50.—Bacillus mucosus capsulatus. (Hiss and Zinsser.)

It has been known to cause nasal sinus trouble, otitis media, endocarditis, and meningitis. The bacteria are found by blood or sputum culture. Agglutination tests are not of value.

Two other members of this group associated with disease in man are *Bacterium rhinoscleromatis* and

Bacterium œznœ. The former is said to cause a slow granulomatous inflammation on the nose, mouth, or larynx, in which hard nodular swellings are formed, containing large typical cells loaded with bacilli. *Bacterium œznœ* is associated with fetid atrophic rhinitis or nasal catarrh.

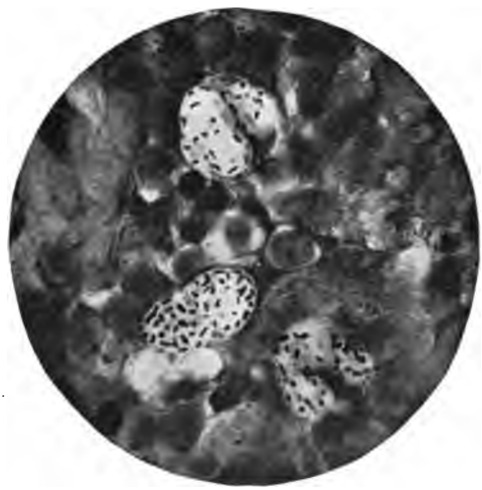


Fig. 51.—Bacillus of rhinoscleroma. Section of tissue showing the microörganisms within Mikulicz cells. (After Fränkel and Pfeiffer.)

All the mucosus group are moderately pathogenic for animals, but injections into these experimentally do not call forth prototypes of the diseases in man. Usually a septicemia with extensive fibrin deposit on serous membranes results. The thick, stringy, or viscid character of the exudates is peculiar to these bacteria. No antiserum has been produced to use in cases of disease caused by them, but there have been

some favorable results after injecting dead organisms during an attack.

Bacterium Bulgaricum.—Another organism not far removed from the group just described, of practical if not of pathogenic importance, is the milk-souring bacillus. There are many varieties, but the one now

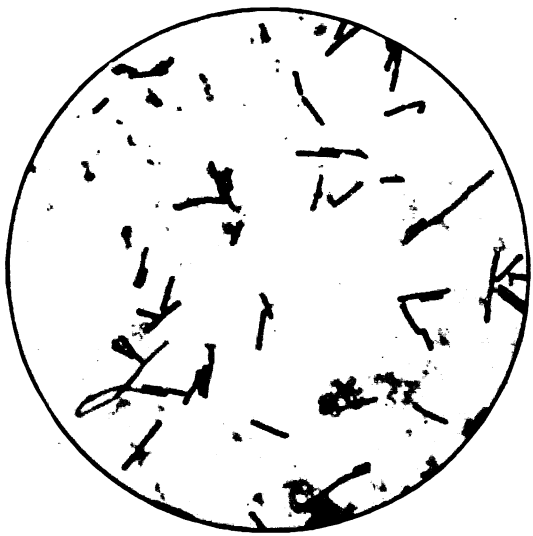


Fig. 52.—Bacterium bulgaricum. × 1000 diameters. (Piffard.)

used most is the *Bacterium bulgaricum* of Massol. It has the property of breaking up the fat of milk and producing lactic acid. This butter milk or sour milk is used in intestinal diseases (see p. 37) at the suggestion of Metchnikoff. The large quantity of lactic acid is inimical to many disease-producing, putrefactive and fermenting bacteria that elaborate poisons,

the absorption of which leads to intoxication to which Metchnikoff ascribed senility and some specific diseases. This observer believed that the health of certain people of the Balkan states could be ascribed to drinking fermented mare's milk (koumyss). The various sour milks now on the market are made by inoculating milk with organisms of this kind. They are probably not superior to domestically prepared buttermilk, if one has a good culture of the proper organism to start with, except that they are apt to be more uniform in content of lactic acid. The writer prefers to give whey cultures of the Bulgarian bacillus so that one can always know how many organisms are being used.

The organism, a large one, from $\frac{1}{12000}$ to $\frac{1}{500}$ inch in length, grows in chains, best at 44° C. or 111° F. in milk, but may be cultivated on other media. The souring of milk takes place within twenty-four hours if the temperature be correct (see Chapter on Milk).

Bacillus Aërogenes Capsulatus of Welch.—A very important putrefactive organism in the intestine is the *Bacillus aërogenes capsulatus* of Welch. This organism grows only in the absence of oxygen. It is a large, straight, or slightly curved rod, from $\frac{1}{25000}$ inch up to $\frac{1}{200}$ inch long by about $\frac{1}{30000}$ inch wide, non-motile, and encapsulated. It has the power of fluidifying gelatin and clotting milk. It is introduced to the human body by wounds probably, or it may go out from the intestinal tract through a solution of the mucous membrane. When lodging in the organs it forms gases, giving an appearance to the liver called a foam or sponge liver. It has an importance in

obstetrics, as gas-infection sometimes appears after mechanical treatment within the uterus. It is probably not pathogenic to entirely healthy tissue, but when an injury devitalizes a part an entrance is afforded. It is responsible for the early bloating of some cadavers.

Bacillus of Malignant Edema.—The bacillus of malignant edema is a common inhabitant of the soil and may be found in dust. It grows only in the absence of free oxygen, but may be cultivated with ease in the laboratory, particularly if sugar be added to the medium. It is a long, delicate rod, measuring about $\frac{1}{25000}$ inch in thickness and $\frac{1}{8000}$ to $\frac{1}{3000}$ inch in length. It moves by flagella arranged along the sides. Spores are formed about the middle of the length. These spores are responsible for the great resistance presented by the germ. The pathogenic properties are due to a soluble separable toxin. The bacteria themselves do not enter the blood stream. At the site of inoculation an edematous and bloody swelling appears which in susceptible individuals spreads rapidly. Death results from toxemia. This germ is frequently responsible for spontaneous disease in the lower animals, but in man is probably only introduced by some mechanical injury. It has been known to be introduced by hypodermic injections when a dirty needle was used. Its most common method of introduction is in grinding dirt into a wound, such as a compound fracture. All discharges or dressings should be so received that they can be burned.

Bacillus Proteus Vulgaris.—The *Bacillus proteus vulgaris* is a widely distributed organism of pro-

nounced putrefactive powers. It is very similar to the colon bacillus. It has been encountered in abscesses, pyelonephritis, endometritis, and peritonitis. Meat poisonings have been traced to it. Its toxin is very poisonous. It is frequently a harmless inhabitant of the intestinal tract. It is quite resistant, and to kill it requires the most approved disinfectants acting over a considerable time.

Bacillus Pyocyaneus.—*Bacillus pyocyaneus* is the organism of green pus. This bacterium is widely distributed on the skin and mucous membranes of man and animals. Its disease-producing powers are low and considerable reduction of resistance on the part of the host may be assumed when infection occurs. It may enter by cracks or wounds, and not infrequently is associated with other bacteria, notably the pus cocci. The pyocyaneus bacillus is an actively motile, straight, or slightly curved, non-spore-forming rod measuring from $\frac{1}{25000}$ inch to $\frac{1}{8000}$ inch long and $\frac{1}{75000}$ inch wide. Its motility is due to one flagellum placed at one end.

It grows readily at room or body temperature, best in the presence of oxygen. On agar jelly it forms pigments which color the growth itself and the medium upon which it is living. These pigments are of two kinds, a green one and a fluorescent one. They impart a beautiful green fluorescence to the tube of culture material. The bacillus has the power to elaborate a gelatin-digesting and a milk-curdling ferment. Its powers of resistance to heat and chemicals are rather high. Materials to be disinfected should be exposed to carbolic acid or formaldehyde solutions for half an hour.

The poisons of the pyocyaneus bacillus are twofold—one an endotoxin, the other a soluble separable toxin. These substances, more especially the latter, have the power of destroying some other bacteria. The broth culture, freed of bacteria and reduced to one-tenth its volume, then called pyocyanase, is used sometimes to rid the throat of persistent diphtheria bacilli. The toxins are more poisonous to animals than are the living cultures. Most small laboratory animals

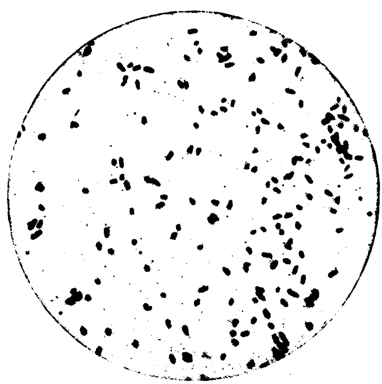


FIG. 53.—Bacillus pyocyaneus. (From Kolle and Wassermann.)

are susceptible to injections of the living pyocyaneus bacillus. The bacilli may multiply within the body and enter the blood stream. It is maintained that some part of the toxin has the power to destroy red blood cells.

The pyocyaneus bacillus may, by its presence on wounds, delay their healing. It is commonest perhaps in boils in the axilla and groin. It has been found in otitis media and in gastro-enteritis of debilitated

children. There may be a general sepsis under which circumstances pleurisy, pericarditis, and the like may be looked for. A diagnosis is made solely by finding the pigment-producing bacillus in pus or other exudate, or possibly by blood culture. Active immunity may be produced in the lower animals by exceedingly careful technic, but it has not been found profitable to use the antiserum upon human beings. We know little as yet of vaccine treatment in such infections.

CHAPTER XII.

YEASTS AND MOULDS.

THIS chapter is devoted to a consideration of the next higher groups of the plant algæ above the bacteria. They are the yeasts or Blastomycetes and the moulds or Hyphomycetes. That there is any sharp separation of these forms from the bacteria, or even from one another, cannot be maintained. There are various gradations in character from the typical representatives of the groups toward the others, so that there are intermediary species incapable of classification. The typical members of each family have very distinct criteria and about them similar forms must be classified.

The yeasts and moulds are very widely distributed in nature, but have but slight pathogenic powers. The former are of importance in the making of spirituous liquors, bread, etc. The moulds have little use, and, except for their frequent appearance as contaminations, and in a few diseases, are of little interest to the pathologist or bacteriologist.

YEASTS.

Yeasts are spherical or ovoid bodies with a doubly contoured wall and a highly granular protoplasm ofttimes with fat droplets in it. They measure from

$\frac{1}{250}$ to $\frac{1}{100}$ inch in length and are about two-thirds as wide as long. The characteristic feature of the yeasts is their method of reproduction, which takes place by a swelling out of a part of the cell wall like a ball, into which the protoplasm flows; this is called "budding." When the daughter-cell arrives at the proper size, the connection with the parent dissolves and the new cell is free. Spores have been observed within the yeast cells, and these develop into adult cells when the old cell ruptures. Yeasts grow upon nearly any organic substance providing there is moisture. The best media and temperatures vary with the species. The kinds pathogenic for man grow best upon foodstuffs containing simple sugars, but may thrive also on complex substances. They are grown with reasonable ease in the laboratory, but care must be used to get them in pure cultures as their development is slow. Their peculiar effect upon carbohydrate-containing stuffs is due to their enzyme which has the power of making ethyl alcohol. How much effect this has upon the production of disease in man is not known.

Blastomycosis.—The disease produced by yeasts in man called *Blastomycosis*, and the causative agent is called *Saccharomyces Busse*, after the man who first described it. By the first, a genus name, it is seen to belong to the same group as the principal beer-making yeast, *Saccharomyces cerevisiæ*. It is not known just how the disease is contracted, but the yeast probably enters wounds, cracks, or hair follicles. It penetrates into the deep layers of the skin and sets up abscesses of slow development and spread. These may break down and leave a sluggish ulcer which later shows a

tendency to heal. More serious phases of this infection are, however, met when the lung is first affected. Then a pneumonia, ending in sepsis, results. In these cases the outlook is hopeless. The disease is probably due wholly to the mechanical presence of the yeasts. The germs leave the body in pus or sputum. They are not easily destroyed, and all infective matter should be burned. It is, however, not a very contagious disease.

FIG. 54.—Saccharomyces Busse. × 350 diameters. (From Kolle and Wassermann.)

There is no antiserum treatment, and the few cases upon which vaccines were tried have not held out much promise in this direction. Yeasts are held responsible for some diseases in lower animals, but the question is not yet settled. When injected into them intentionally varying results are obtained. It can be said that they settle by preference in the lungs and spleen.

MOULDS.

This group is by no means so simple as the yeasts. The following remarks pertain to those forms having some importance in human medicine. The moulds or branching fungi consists of long, interlacing, hair-like threads called mycelia (sing., *mycelium*), from which come off end branches called hyphæ, upon

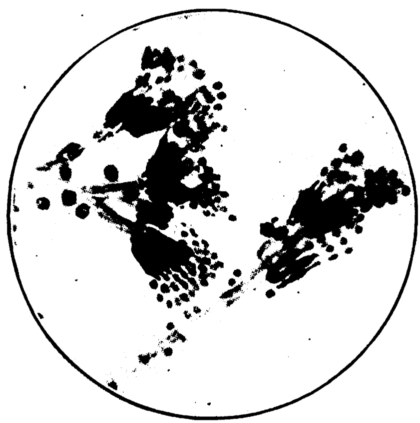


FIG. 55.—Penicillium glaucum. Gelatin culture. Spread stained with gentian violet. 500 to 1. (From Itzerott and Niemann.)

which the reproducing parts usually develop. These mycelia are made up either of one long, continuous cell with a cell wall, and an easily distinguishable, long nucleus, or they may break up into shorter forms each with a separate nucleus. Their length and width are so variable that measurements would be misleading. Their general naked-eye appearance and size is well known to any who have observed the felt-like or cottony moulds upon decaying organic matter.

Multiplication occurs in two ways. Upon the hyphæ may develop a reproductive organ, the sporangium, containing spores that become free upon its rupture. Or

FIG. 56.—These two half-plates show three months' growth on peptone-maltose agar of two megalosporon varieties of the ringworm fungus. Natural size. (Park.)

the hyphæ may split into segments, giving off end-pieces as reproducing elements, called conidia, the whole giving the appearance of the hand bones, the phalanges representing the conidia (see *Penicillium glaucum*).

These moulds enter by wounds, cracks, or hair follicles, and develop in the superficial layers of the skin. The mechanical irritation set up by their presence is largely responsible for the various diseases they occasion. To be sure, they can form enzymes, but of what importance they are in human lesions is not known. The diseases are not highly contagious, but

Fig. 57.—Achorion Schönleinii. (Flügge.)

of great tenacity when once well advanced. Infective material comes away in all cases with discharges, and should be burned. Their principal diseases in the human being are as follows:

Ringworm.—Of this there are two varieties—ringworm of the skin, *Tinea circinata,* and ringworm of the

hairy portions, *Tinea tonsurans* or *Tinea sycosis*. This is due to the *Trichophyton* of various species, depending upon the size of the spores. It is commonest in children in schools, and appears also where uncleanliness prevails, as evidenced by epidemics from a badly kept barber shop. The fungus grows into the hair sheath and inflames its base. The disease appears characteristically as circular, scaly patches, which are rapidly denuded of hair. This disease, as far as known, is only transmitted from man to man.

Favus.—This disease is caused by a mould called *Achorion Schönleinii,* and affects chiefly the hairy portions of the body. Animals as well as man are affected, and while it is usually transmitted from person to person, it is not uncommonly contracted by fondling affected cats and dogs. Debilitated persons are most susceptible. The fungus penetrates the hair shaft, sets up a little inflammation which slowly spreads, and is soon covered with a curious sulphur-yellow concave crust called a scutulum. The place becomes bald because the nutrition of the hair is cut off. Some cases are on record where this fungus has spread to all the tissues of the body, doing damage by the irritation of its presence.

Thrush.—Thrush or soor is a disease caused by the *Oïdium albicans,* and is characterized by the presence of small white patches on the mucous membrane, usually of the mouth, in unclean or illy nourished children. It may be found in the vagina. It has been known to spread throughout the body.

Pityriasis Versicolor.—This is a disease chiefly of unclean persons produced by the development of

Microsporon furfur in the superficial layers of the epithelium. It may appear anywhere on the body, but chiefly affects the short-haired skin. It is very slightly contagious.

Diagnosis.—The diagnosis of these conditions depends upon finding the particular fungus. Some of the pus from a blastomycotic abscess or some of the scales

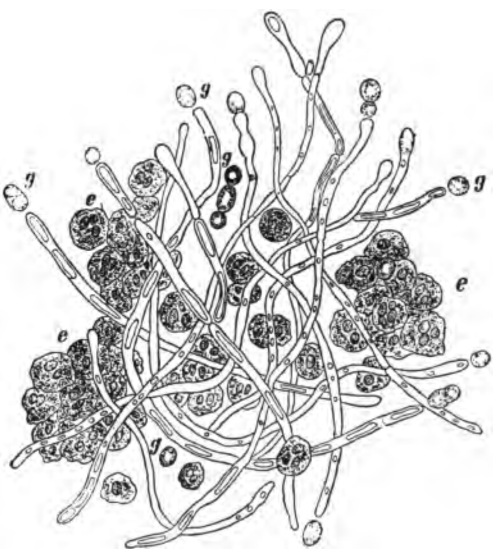


FIG. 58—Oïdium albicans: *g*, conidia; *e*, pus cells. (From Plaut, in Kolle and Wassermann.)

from the underside of the crusts of the skin diseases produced by moulds is softened in weak caustic and examined in a moist condition under the microscope. The single or budding cells of the yeasts or the branching mycelia of the moulds are usually found with ease. In case it is desirable to cultivate the fungi a long elaborate technic is necessary.

CHAPTER XIII.

BACTERIA IN AIR, SOIL, WATER, AND MILK.

BACTERIA IN AIR.

THE bacteria naturally found in air are not pathogenic, but consist usually of spore formers and moulds; in other words, those having some resistance to dryness and sunlight. There are more in the layers of the atmosphere near the earth, circulating in air currents after being raised in dust. When there are no currents, bacteria tend to settle on surfaces, as they are heavier than air. After rain storms the atmosphere may be nearly free of organisms. More pathogenic forms are found where people live or congregate, so that air currents produced by human activities tend to increase the bacteria floating about. Colon bacilli are sometimes found in the air above streets. Organisms may be carried in currents set up by coughing or blowing. This is well shown by the fact that tubercle bacilli has been found at a distance of twenty feet in front of a coughing consumptive. The practical application of this principle is the use of moisture in dusting or sweeping. Surfaces of a sick room should be wiped with a moist cloth, preferably using a disinfectant that will not hurt the hands. Bacteria have no power to leave a moist surface. They may be freed by the bursting of bubbles of sputum or other infective fluid.

They do not travel far by this means if air currents be absent, and there is probably little danger from simple unpleasant odors from drains if protected from these currents. Bacteria are found in air by filtering a definite quantity of air through cotton or sugar. The former is washed, the latter dissolved in sterile water, and this is examined as outlined under water.

BACTERIA IN SOIL.

Microörganisms live in the first few feet of the earth wherever moisture and a small amount of nourishment are found. Pathogenic forms are near the surface, while deeper in pure saprophytes are found. Bacteria are deposited from dust, water, and the dejecta of animals. Pathogenic ones are only to be found where animal life exists, while in uninhabited or untilled lands they probably do not exist at all. The denser the population the more disease-producing kinds are found. Rain will wash away soil and carry with it bacteria into water courses. This is of great importance where human dejecta are deposited on the ground.

Typhoid fever epidemics have been known to have such an origin. Typhoid germs can live in soil for many months. Vegetables are easily contaminated, and if eaten raw can transmit the disease. Cholera vibrios have a shorter life in this place. Anthrax bacilli live a long time and cattle are sometimes infected by their pasture. Actinomycosis is well known to spread through a herd because of infected pasture land. The bacteria of soil are found by planting some of it

in laboratory media, placing a part at ordinary temperature and another at body temperature. By the latter means the forms parasitic to animals are found. Tetanus bacilli are, perhaps, the most wide-spread of pathogenic bacteria in the soil. Their resistant spores remain alive an unlimited time. Persons going barefoot and subject to wounds or bruises may contract the disease. Tubercle bacilli, in dead persons, live only a few months, but when contained in sputum spat upon the earth survive for a long period.

BACTERIA IN WATER.

In water there are many hundreds of species, but it may be said in general that all the disease-producing kinds are in water because discharges from human disease have been put into it. Of course this may not be direct, but through the agency of soil as mentioned above. Some bacteria may be carried into streams by rain which brings down the dust. Rain itself is free of germs. Bacteria may be present in water up to the billions without altering greatly its clearness or giving it an odor, while, on the other hand, a cloudy water does not necessarily indicate bacterial pollution, for the turbidity may be due to harmless inorganic chemical matter. Of the two water sources recognized by hygienists, ground water (deep wells) and surface water (ponds, lakes, and rivers), the second is by far the more important and the more easily polluted. Large bodies of water, either still or moving, tend to rid themselves of bacteria. In still or slowly moving bodies, such as reservoirs, germs settle with other

organic and inorganic matters. For water-courses of any character purification is aided by changes in temperature during the day and night and the very efficient disinfecting properties of direct sunlight. Oxygen absorbed from the air also assists in destroying bacteria. There are certain saprophytes in water and sewage capable of breaking up organic matter and freeing oxygen, which, either free or in going into combination with other elements in chemical union, is inimical to pathogenic non-spore-forming bacteria.

In this book a word may be useful as to the means of artificially purifying water for domestic purposes. For the community water is purified by settling in reservoirs, or by filtration through sand and stones, sometimes aided by the addition of chemicals. For household purposes bacteria in water may be removed by house filters made of porcelain attached to the house supply, or what is better, by boiling. Domestic filters must be taken care of by some one thoroughly familiar with their operation and cleaning, otherwise they do not deliver safe water. The flat taste of boiled water may be removed by allowing air to go through by pouring from one container to another several times.

Water in a shallow vessel, preferably of copper, will be practically sterilized by an hour's exposure to direct sunlight. This is practicable for camping parties who are compelled to use water under suspicion.

Principal Water-borne Diseases.—The principal diseases transmitted by water are typhoid, cholera, and dysentery. Typhoid bacilli may live in water, especially if surrounded by a bit of protective and nutrient

organic matter, for many weeks. The question is often asked as to how a few germs in a glass or two of water can cause typhoid fever. As a matter of fact, when an epidemic of typhoid is starting there are usually supposed to be many germs and not a few in the water. What probably happens is that a small particle of organic matter, possibly feces, is swallowed. This may contain many thousand organisms.

Although cholera organisms live in water a shorter time than typhoid bacilli, they are said to be viable for several weeks. Relatively more cholera organisms are discharged with a cholera stool than is the case of typhoid bacilli in enteric fever. Dysentery bacilli live only a short time in water probably, and the importance of water in the dissemination of dysentery is questioned by some observers. Certain it is that some epidemics appear to be water-borne.

Typhoid and colon bacilli are always present in typhoid stools. It is hardly probable that the former could get into water without the latter. Moreover, the colon bacillus is present in all alimentary tracts. It is more easily detected in any mixture or solution than any other of the intestinal bacteria. Therefore it is taken as an indication of sewage pollution in water. This may not mean that typhoid bacilli are present, but merely that contamination of water by sewage from animal sources has occurred. Whether from man or animals, it is obvious that dejecta should not come into water intended for human consumption. The methods of water examination now in use all aim at the detection of *Bacillus coli*. Because of its peculiarities in the fermentation of sugars, certain media are adopted as

standards for its isolation. Water is carefully collected and kept upon ice so that no increase of bacteria will occur. In the laboratory suitable measures are taken to determine the whole number of bacteria and the presence of the colon bacillus. The whole number is estimated by growing the water in flat plates of agar jelly and counting the number of colonies growing in forty-eight hours. It is assumed that each colony grows from a single bacterium. Chemical examination of water aims at the determination of the quantity of organic matter indicative of sewage pollution. Standards have been set by sanitarians, but they are not necessary here.

BACTERIA IN MILK.

Milk in the deeper parts of the udder of the healthy cow is probably wholly free from bacteria. The ducts of the teats, however, are almost never free from some germs, and of course the outside skin contains many. In a diseased udder there may be not only the germ causing the disease, but other intruders from the outside. Bacteria come into milk from the cow herself or from the outside. The latter is probably the more important and the factors which must be considered are the dirt on the skin, swishing of the soiled tail, the soiled hands of the dairyman, and the cans, contaminated by manure or by polluted water. The ordinary milk bacteria are fortunately not pathogenic, the dangerous varieties from the cow being only streptococci from inflammation of the udder, and tubercle bacilli. Those forms getting into milk from the sur-

roundings in the dairy are only important in causing souring of the product.

Milk is a capital culture medium for almost all bacteria, and as it is warm when drawn, growth may begin shortly. Unless the milk be cooled very soon, to a temperature at which bacterial growth is retarded or stopped, souring will occur. Perfectly fresh milk has a very slight restraining influence upon the development of some feebler bacteria, but this power is soon lost and bacterial growth may be unlimited. It is best to keep milk not above 40° F. or 5° C., but so low a temperature is not always possible to maintain. The consumer should strive to keep milk at the lowest temperature practicable. Cities are now controlling their milk supply by various regulations as to the dairy management and shipping systems. The most important domestic means of having clean milk consists in receiving it in perfectly clean bottles and keeping it on ice.

Pasteurization.—On account of the lack of perfect municipal control of the milk supply, it is necessary to resort to Pasteurization. This consists in heating the milk to 60° or 70° C., 140° to 158° F., for ten to twenty minutes, and then cooling rapidly. Various methods are in use commercially, but this can be done very easily in the home, using a double boiler and a thermometer. Pasteurization kills all but the spores of putrefactive bacteria, which are of little danger if the milk be kept on the ice or used shortly. Some persons object to the use of this heating because the food value of the milk is reduced by making certain chemical constituents harder to digest. The casein

curds of milk become tougher after boiling. There seems to be no proof for the statement made in certain quarters that pasteurization causes the elaboration of poisonous substances in milk. However, some German pediatrists are now using boiled cows' milk for certain intestinal disorders of children. If properly carried out, Pasteurization does more good than harm, and has proven its value by the reduction of the death rate from infantile diarrhea in summer time. The greatest objection anyone can raise to Pasteurization is that it gives a false sense of security. It cannot be too strongly emphasized that any natural antibacterial power possessed by the raw milk or the restraining influence of lactic acid bacilli on putrefactive bacteria is destroyed by Pasteurization and that rigid precautions should be observed that the heated milk is not allowed to remain at a temperature permitting the growth of bacteria. If kept below 60° F. and used within twenty-four hours the consumer is probably safe at all times.

Spoiling of Milk.—In the summer conditions for the spoiling of milk are more favorable than in winter, since the temperature is unfavorable for its preservation, and more dust and flies introduce bacteria. Bottles in which milk is served should be washed when empty, with cold water first, and then boiled or well scalded. If a small quantity of milk remain in the bottom, putrefactive and fermentative bacteria grow and dry on the bottle, making it harder to clean subsequently. Milk bottles should be considered as possible carriers of disease and the user should assume his part of the responsibility by cleaning them out

and not leave it entirely to the milkman. The author knows of one instance where a milk bottle was used as a spittoon.

Souring of Milk.—The souring of milk is due to a variety of bacteria, chief among which is *Bacterium lactis aërogenes*, related to the *Bacterium bulgaricum* described above. This germ is ubiquitous. It is not pathogenic. It produces a fermentation of the sugar of milk, lactose, into lactic acid. Moulds may help this and oftentimes lactic acid and ethyl alcohol may be formed side by side. The latter predominates in the carbonated milks like koumyss. Other bacteria cause clot, or precipitation of the casein, the forerunner of cheese. Streptococci from the udder or manure may also help in souring.

To make buttermilk in the home is a simple matter. A quantity of whole or skim milk is boiled and cooled. A tablet containing the lactic acid bacilli, a small quantity of pure culture of the organism, or a "starter" from a previous making is then added to this cooled milk and set aside in a warm room (about 75° F.) overnight. The result is a rather agreeable sour milk. Pharmaceutical chemists and laboratories are now supplying tablets and cultures for this purpose. (See page 188.)

Diseases Caused by Polluted Milk.—Many diseases are believed to be due to bad or polluted milk. If milk merely carry the germs this is easily understood, but as is the case in the diarrheas of infants, the trouble may lie not with the bacteria introduced with the milk, but with the disturbance of digestion caused by the abnormal chemical conditions brought about

by souring. These strange chemical substances so pervert normal digestion that really pathogenic bacteria, the dysentery bacillus group, for example, are able to exert their noxious effects. Streptococci commonly present in the teats, identical with the *Streptococcus pyogenes*, are said by some to take advantage of this disturbed digestion. The examination for streptococci consists in simple staining and finding of them lying in or about pus cells. Health authorities have rules covering this method of examination and the interpretation of results.

Scarlet Fever, although its cause is unknown, is known to spread along milk routes and has at times been traced to a case on a dairy farm. Foot-and-mouth disease of cattle, another condition of unknown etiology, has been found in children drinking milk from affected cows. The bacillus of diphtheria may live in milk a long time and may be carried along a milk route. It is said that cholera may be transmitted by milk contaminated with polluted water.

Typhoid Fever.—Typhoid fever may be transmitted by milk when a case exists on a dairy farm or a dairyman uses polluted water to wash his cans. In perfectly fresh milk the germs do not thrive, although they are not destroyed, but when a little older the milk offers no resistance to their multiplication. If sour, the lactic acid and alcohol not only inhibit their growth, but actually kill them. It is frequently in the period from cooling to distribution and use that contamination occurs. This is done by the hands of dairymen, shippers, tasters (dipping the finger into the milk), or by domestic servants. Carriers of typhoid

bacilli are a prolific source of epidemic spread by milk. One of the carriers mentioned on page 121, went to work on the dairy farm of her brother immediately after the death of her husband. In three weeks twenty-eight cases of typhoid broke out on the farm and among those using its milk. Although some sanitarians discredit the milk transmission of typhoid, the following observation is very significant when taken together with the fact that the *Bacillus typhosus* has been found in milk. There is a relatively greater number of women and children affected in milk-borne epidemics, while in water and general epidemics more men are affected. Pasteurization easily kills the typhoid bacillus.

Tuberculosis.—The question of the transmission of tuberculosis by milk is one that has raised much discussion, since Koch said that the bovine type of bacilli does not produce tuberculosis in human beings. The matter seems settled now that tuberculosis in the young may be caused by the bovine bacillus, and is most commonly located in the cervical and abdominal glands and in the meninges. If a cow have tuberculosis of the udder, tubercle bacilli are usually found in great numbers in the milk. If she have lesions elsewhere she may still excrete the bacilli in the milk, but it is impossible to determine when or in what numbers. The obvious indication is not to use milk from a tuberculous animal. Tuberculin tests are now being required almost everywhere when permission to register a milch cow is asked. No cow giving a tuberculin test should be used for a milk supply. Bacilli are also excreted in feces of infected animals,

and are easily carried into the milkings by the swishing tail. Tubercle bacilli of human sources may, of course, be in milk if handled by a consumptive. Pasteurization does not surely kill the tubercle bacillus, especially if surrounded by a bit of mucus.

Examination of Milk.—Milk is examined for the presence of colon bacilli, and the whole number of bacteria just as in the case of water. For the demonstration of tubercle bacilli by stain a special technic is necessary. We usually inject some of the milk, cream, or sediment into guinea-pigs, and expect lesions in them. The chemical examination of milk usually shows its food value, which may be affected by bacteria.

CHAPTER XIV.

DISEASES DUE TO PROTOZOA.

There are not many recognized specific diseases in man due to these lowest animal forms, but those well known are of the greatest importance, because of their prevalence in some parts of the world and on account of the difficulties presented to medical treatment. It may be said in general that the protozoan diseases of man represent a phase in the life history of the causative microörganism, and are in fact stages through which the protozoa pass in order to fulfil their cycle of life. The subject of protozoölogy is of enormous magnitude, and it is impossible even to outline in a work like this all the steps which may be passed through. An attempt will, therefore, be made to describe the important diseases due to protozoa, with a general statement covering the morphology and life history of the organism. Of the many thousands of species in nature only a handful are pathogenic for man. The disease-producing types fall into the following zoölogical families or genera: Sarcodina (rhizopoda, amebæ) Mastigophora (flagellata, trypanosoma), Infusoria Heterotricha (balantidium), Sporozoa (coccidia, hemosporidia, plasmodium). The diseases, we shall see, all fall into these groups. They are for the most part dependent upon the animal body for the continuance of

their life. Other forms live in water, earth, decaying matter, or as apparently harmless commensal species within the intestinal tract of animals from insects up.

SARCODINA.

Amebic Dysentery.—Amebic dysentery is a subacute or chronic inflammatory disease of the large intestine, caused by the *Entameba histolytica* or dysenteric ameba. It is not definitely settled as to the means by which

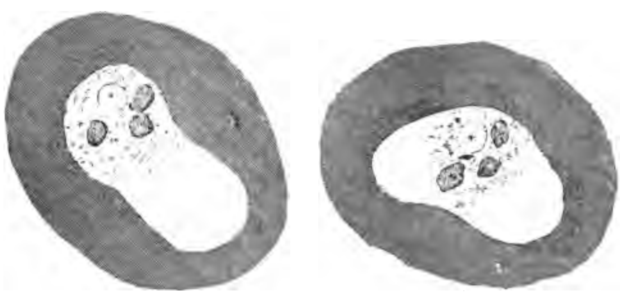


FIG. 59.—Entamœba histolytica (Schaudinn) from the stool of a dysentery patient. The same individual showing two successive movements. The nucleus contains the nucleus and three red blood cells. Enlarged 500 to 1. After Jürgens (from Kisskalt and Hartmann.)

this protozoön is transmitted, but water is probably the most important method. The cells multiply in the small intestine, pass downward, and penetrate the mucous membrane of the colon. Here in the deeper layers they set up the inflammation largely by their presence, but also by some soluble excretory substance. From here they may be carried throughout the body, and give rise to abscesses notably in the liver. These are

of long standing, and may present work for surgical interference.

The protozoa leave the body with the feces, which to be disinfected must be well treated with carbolic acid or burned. They should never be allowed to dry, because the entameba may become more resistant in a dry state, due to a curious spore-like stage. This disease is diagnosticated by finding the parasites in the feces or pus, which must be kept at a proper temperature during the examination. Some of the material is examined on a warmed plate and kept not lower than 77° F. all the time. At this degree the peculiar movements of the amebæ are noted as a pushing out of a part of the cell wall like a bud. This is the pseudopod or false foot. This means of progression enables the organism to penetrate intact mucous surfaces and pass through sand filters impermeable for bacteria.

The *Entameba histolytica* is an irregularly shaped mass of simple protoplasm with a primitive structure. Its nucleus is usually single in contrast to other amebæ. It measures up to $\frac{1}{500}$ inch. It moves and embraces its food by the pseudopods. It reproduces by division or by the production of daughter-cells within its body. When these are massed together and held by a capsule, it is said to be encysted. When such cysts are taken into the body the intestinal juices probably dissolve the capsule and let the cells go free. Encystment occurs when conditions for life become unfavorable. Amebæ are not killed by cold, but succumb to 60° C. or 140° F. in one hour. Acids are unfavorable for the growth. They are cultivated artificially with great difficulty, and are usually combined with bacteria,

in whose presence they multiply without hindrance. Only monkeys and dogs are susceptible to the amebæ causing disease in man. No therapy depending on antitoxins or vaccines is practicable.

MASTIGOPHORA.

Kala-azar.—In the next group of protozoa, the flagellata, several are pathogenic for man. Kala-azar is a peculiar, slow disease, called by various names, depend-

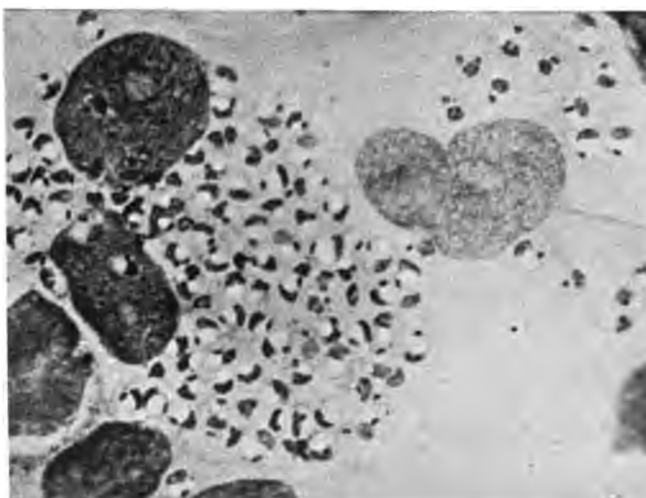


Fig. 60.—Protozoa in a case of tropical ulcer. × 1500 approximately. (After Wright.)

ing upon its locality—dumdum fever, kala-azar, etc.—exhibiting a large spleen, hemorrhages, anemia, and fever. The causative microörganism may be found

almost anywhere in the body, but chiefly in the spleen, whence it may be obtained by puncture with a needle. It is said that bed-bugs and mosquitoes transmit the disease. The protozoön responsible, *Leishmania Donovani,* is an ovoid or circular or comma-like mass with two nuclei, and one moderately long

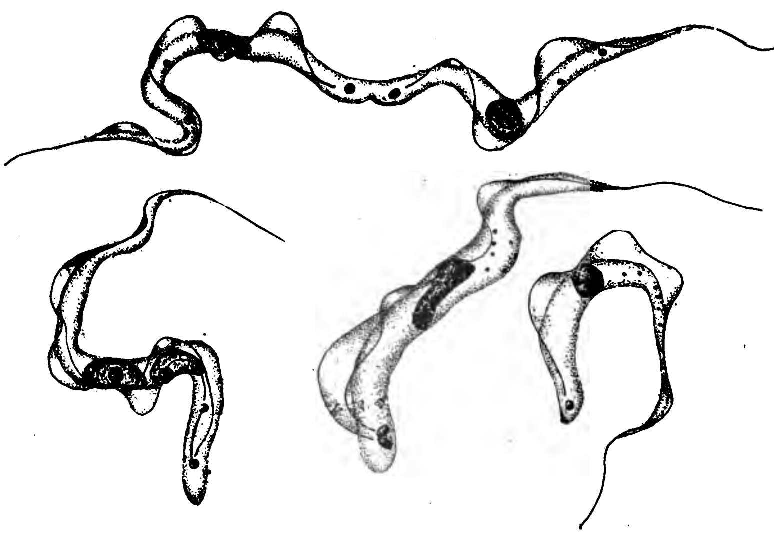


FIG. 61.—Trypanosoma gambiense. (From Calkins. Preparation by F. W. Balstack.)

flagellum on the forward end. They are from $\frac{1}{12000}$ to $\frac{1}{8000}$ inch long and about two-thirds as wide. See Fig. 60.

Trypanosomiasis.—The next flagellate to cause disease is the *Trypanosoma,* two species of which are pathogenic for man, causing a disease called trypanosomiasis, or sleeping sickness. This affection is com-

monest in Africa, because of the prevalence of the tsetse fly in whose body the protozoa are transmitted. The bite of these flies becomes infective for the well three days after biting the affected, and continues so for about four or five weeks. These pests bite during the daytime, so that protection and screening of houses is insufficient usually to guard against disease. Of course the infected persons as well as the healthy must be protected from insects. Inasmuch as it is thought that some species of trypanosomas in the blood of the lower animals are infective for man, strict quarantine is placed on animals within countries where this disease exists, and upon exported specimens.

When the protozoa come into the blood they are carried throughout the body and lodge chiefly in the lymph glands, an enlargement of which is an early sign of infection. When the disease is well settled we see progressive anemia, weakness, and sleepiness, whence comes the name "sleeping sickness." The end comes from profound anemia and prostration. Pains and dropsical collections are common. The disease lasts a varying time. The early stages are slow, but when the great depression begins it usually progresses rapidly to a fatal end. The changes produced are those of obstruction to the lymphatic system and low-grade chronic inflammations. The micro-organisms are present in the blood, all organs, including the lymph glands, and the cerebrospinal fluid. From all these places they may be recovered in making a diagnosis.

Trypanosomas are irregular, elongated, twisted bodies with a large nucleus variously placed, and a

thickened ribbon-like edge, the undulating membrane, which starts as a minute secondary nucleus at the hind extremity and ends in a rather long whip-like flagellum at the fore end. They range from $\frac{1}{500}$ inch to $\frac{1}{800}$ inch in length and they are about $\frac{1}{1500}$ inch wide. They move by a sinuous, jerking, boring action. Division takes place by longitudinal splitting, probably beginning at the hind end and proceeding along the undulating membrane. The true nucleus shows its division late. The human trypanosoma has resisted artificial cultivation until very recently, and at the present time it is very difficult to cause development in the laboratory. Other forms of these protozoa have been grown with comparative ease. Most animals may be the hosts of trypanosoma; in some there will be disease, in others the organisms live as harmless commensals. The modern treatment consists in using an arsenic preparation called atoxyl. Numerous attempts have been made to produce a serum by injecting animals with trypanosoma. Sera thus obtained have a slight beneficial effect upon the lower animals, but have not proven of great value with human beings. The injection of attenuated cultures has raised the resistance of certain lower animals. The fact that some resistance can be attained by attempts toward the production of active and passive immunity indicates that trypanosoma exert their action by some poison. Whether it be in their bodies or elaborated in the juices about them is not known.

Trichomonas.—Two protozoa of a slight medical importance are the *Trichomonas vaginalis,* with its nearly related varieties, *T. intestinalis* and *T. pulmo-*

nalis, and the *Lamblia intestinalis*. These forms may infest the vagina, intestine, or lung, and cause some irritation, probably not particularly inflammatory. They are held responsible oftentimes for the inflammation set up by bacteria gaining entrance at the site of the irritation by the protozoa. However, the vaginitis and cystitis caused by the *T. vaginalis* are serious matters in children. These are usually pear-

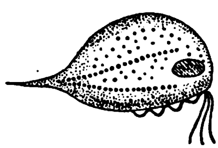


FIG. 62.—Trichomonas vaginalis. (Blochmann.)

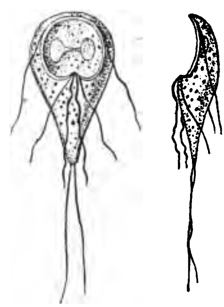


FIG. 63.—Lamblia intestinalis. (Schewiakoff.)

shaped bodies, with prominent nucleus and well-marked anterior flagella. The trichomonas has a heavy undulating membrane.

SPOROZOA.

Malaria.—The most important disease caused by protozoa is malaria. This is an infectious disease characterized by intermittent chills, fever, and sweats, with prostration and progressive anemia. It is common in lowlands, where stagnant water collects, or in the vicinity of slowly moving water, permitting the

propagation of mosquitoes. It is not communicable by contact of man to man. It is the infestation of the red blood cells by a parasite having three forms, belonging to the order *Hemosporidia.* The parasites are called the *Plasmodium vivax,* the *P. malariæ,* and the *P. falciparum.* Three types of attack correspond to the three protozoal species: (1) That which gives chills and fever every third day, the tertian malaria; (2) one where the paroxysm appears every

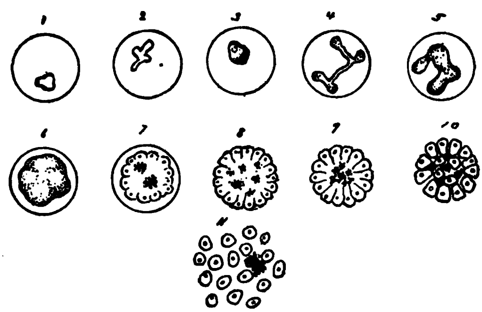


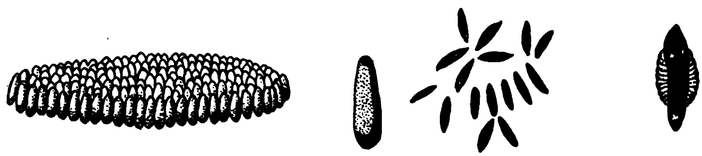
FIG. 64.—Some of the principal forms assumed by the plasmodium of tertian fever in the course of its cycle of development. (After Thayer and Hewetson.)

fourth day, the quartan type; and (3) a continuous, typhoid-like type, the malignant or estivo-autumnal fever.

The species vary in finer morphological details, but they follow the same course in their transmission and development in regard to infectivity, except that they require differing times for their full development.

The female mosquitoes of the genus Anopheles carry the disease from one person to another. They fly and bite in the early evening. These mosquitoes may be

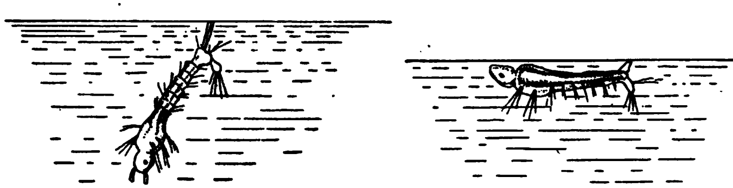
recognized by their position on a surface. Their body forms a large angle with the surface, and the head is on a line with the body. The ordinary mosquito, Culex, stands parallel with the surface with the head



a *b*

FIG. 65.—Egg of Culex (*a*) laid together in "small boat;" those of Anopheles (*b*) separate and rounded. (From Kolle and Hetsch.)

bent down. Furthermore, the wings of the Anopheles are furred on the flat surface, while the Culex wings are only fitted with widely set, fine hairs on the edges. There are many other differences, but these will suffice as general guides. The female mosquito bites



a *b*

FIG. 66.—Larva of Culex (*a*) hangs nearly at right angles to water surface; those of Anopheles (*b*) are parallel to the surface. (From Kolle and Hetsch.)

a malarial person and receives the parasites into her stomach. Here they undergo reproduction by a sexual process, and appear in her salivary gland in a condition ready for transmission to the next person bitten.

This gland is connected with the biting apparatus, and some of its secretion is left under the skin when the mosquito bites and sucks blood. It is probably the secretion from this gland which causes the itching of the ordinary mosquito bite. This reproduction in the mosquito requires seven to ten days. When a

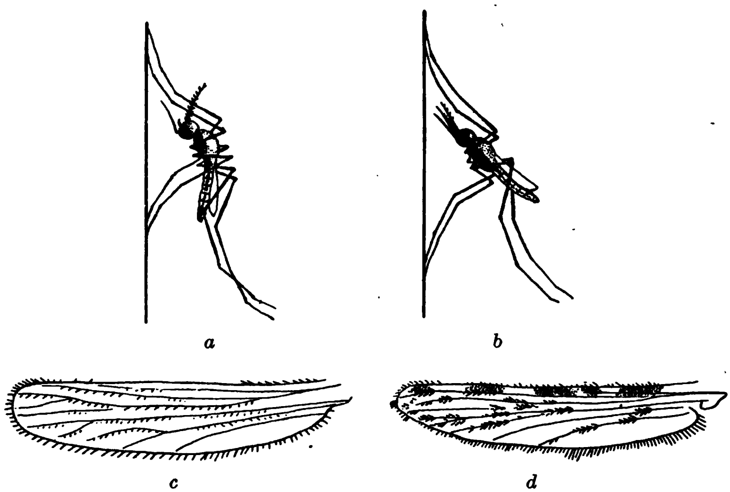


FIG. 67.—Body of Culex (*a*) when resting is held parallel to wall in a curved position, that of Anopheles (*b*) at an angle of about 45 degrees and is straight; wings of Culex (*c*) are generally not spotted; those of Anopheles (*d*) are spotted. (From Kolle and Hetsch.)

person is bitten the parasites, left under the skin, penetrate their cell of choice, the red blood corpuscle. In the body of this cell they have the power of undergoing an asexual division (see Fig. 64). The minute form swells into a large body and breaks up into small spores. When this mass of young forms has reached a size too great for the red cell the latter bursts, syn-

chronously with which we have the chill. By this bursting young forms are again set free in the blood, each capable of entering other red blood cells. Of course, not all the cells are affected, but in severe cases one of every thirty red blood cells may contain the parasites, but as the disease progresses and successive

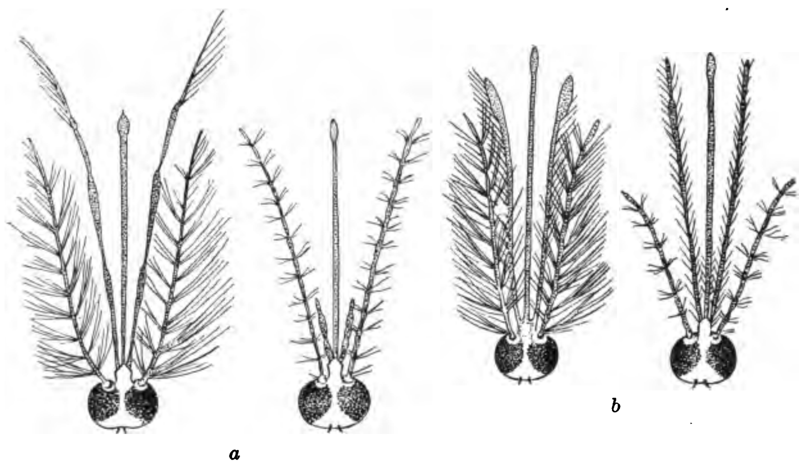


Fig. 68.—In Culex the palpæ (*a*) of the female are very short, of the male are longer than the proboscis; in Anopheles the palpæ (*b*) of both sexes are about equal in length with the proboscis. (From Kolle and Hetsch.)

crops of corpuscles are destroyed the sum total of the damage may be great. As a result of this, severe grades of anemia result. The cycle of development from the young form to the bursting requires forty-eight hours for the tertian malaria and seventy-two hours for quartan malaria, while in estivo-autumnal malaria there is a slowly progressive attack on suc-

cessive cells by a curious extracellular and intracellular crescent-shaped body.

The anatomy of these plasmodia is of great intricacy, and undergoes so many changes that it is hardly desirable to go into detail here. Suffice it to say that it is a body when adult somewhat larger than a red blood cell, full of actively moving granules. The young forms are homogeneous, and are found with the greatest difficulty except when specially stained. They probably get all their granules from the destruction of the red blood cells. Some adult forms have flagella about their wall. The power of producing disease lies partly in their destruction of the important cells of the blood and partly in a poison they produce. The internal organs, especially the spleen, are injured first by the damage to the blood, and secondarily by the extra work thrown on them in trying to destroy the parasites and to remove the pigment which is liberated by the cellular disintegration. A slight immunity remains after an attack. There is a relative racial immunity among the negroes. The cases that do not wholly recover or that have remote recurrences are said to be harboring quiescent parasites in the spleen. A chronic inflammation of this organ often results.

Diagnosis.—The disease is diagnosticated by making fresh or dried and stained preparations of the blood and examining them under the microscope. Should malaria organisms be present, faint, irregular shadows or larger bodies filled with dancing granules are seen in the unstained blood, while in stained smears fairly well-colored parasites containing quiet granules will be

found. Animals are not susceptible to human malaria. Monkeys may be artificially infected. No antiserum or vaccine treatment is possible now. Quinine is a specific, and if properly used will cure all cases. The spread of malaria is checked by preventing the propagation of mosquitoes. These insects lay their eggs on the surface of quiet water. The young remain at the surface of the water when they require air. Oil is spread upon the surface of the water and all marshes are drained. No increase of the insects can go on if these two things are done.

CHAPTER XV.

DISEASES OF UNKNOWN ETIOLOGY.

WHILE this book concerns itself with the relation of microörganisms to disease, it is fitting that mention be made of some communicable affections, in which the causative agent is not yet known. The clinical observations upon these infections indicate that they are due to some form of living body which present methods of investigation do not permit us to demonstrate. It is inconceivable that so specific a condition as smallpox should come from anything but a self-reproducing agent. Nevertheless the viruses of these diseases must be, at least in some part of their existence, very tiny, because they are able to pass through the pores of a porcelain filter that would hold back bacteria. For this reason the following diseases are said to be due to "filterable viruses." We may later learn to know the agents as physical entities, but those which can be cultivated now are only imperfectly understood.

Smallpox or Variola.—This is an acute infectious disease characterized by severe constitutional symptoms and a rash which becomes pustular, leaving behind it after recovery peculiar depressed scars. It is believed today that the various affections of man, cow, horse, and sheep are practically identical. Certain it is that

infection with cow-pox will give resistance to human smallpox. Vaccination was formerly practised by transferring the pox from person to person, but now fresh material is used from a cow which has been artificially infected with smallpox. By passing this virus through the calf it is so altered that it cannot produce smallpox in man yet it can, when inoculated into the skin, call forth an immunity against subsequent infection with that disease. Jenner, in 1798, was the one who first developed the principle of using cow-pox in the protection against human variola. The exact cause of smallpox is not known. It is supposed to spread by contact either directly with the sick or indirectly by objects having been in contact with them. Such objects are called fomites. Bacteria are present in the pustules caused by vaccination and in the eruption of smallpox, but they have been proven to be secondary invaders.

Rabies or Hydrophobia.—This is an acute infectious disease to which nearly all animals are susceptible, characterized by slowly progressive palsies and delirium. Hydrophobia means fear of water. Such an emotion does not exist, but animals merely avoid water because they cannot swallow it. The cause of rabies is excreted in the saliva and may be transmitted by the bite of a rabid animal, or by getting the saliva into an open wound. The virus is innocuous if swallowed. After having entered the body the virus travels to the central nervous system and remains there throughout the whole attack. The spinal cord particularly is involved. The only evidence there is of the actual causative germ is the presence of minute

stainable granules in the nerve cells of the brain. These so-called "Negri bodies" are demonstrated by special staining methods. When a dog is suspected he is killed and his brain removed. Bits of it are stained for microscopic examination and other pieces are made into an emulsion, which is injected into the brain of a rabbit. If rabies virus be present this susceptible animal will die within three weeks as a rule. Recently attempts at the cultivation of the rabies virus have been rewarded by the development, under anaërobic conditions, of minute globoid bodies with a tiny nucleus and with such cultures animals have been infected.

Pasteur found a method for protective inoculation treatment against rabies. He found that if the spinal cord of a rabbit suffering from rabies were removed and dried in a vacuum it lost its virulence for other rabbits. If he dried it two weeks nearly all of the virulence was lost, but if only two days, its strength was only slightly impaired. He found that if he inoculated animals with gradually increasing strengths or quantities of emulsions made from these dried rabbits' spinal cords, a certain degree of immunity was obtained. This principle is now used in treating persons bitten by rabid animals. The treatment is possible after the bite and the outlook is better the sooner after infection the treatment is begun. The spinal cords of rabbits are ground up in glycerin and injections are made under the skin. The patient first receives a dose from a cord dried fourteen days, then from one dried twelve or thirteen days, then ten or eleven days, and so on until one dried two days is used. The mortality

from rabies has been greatly reduced by this method of active immunization. At present there is no very accurate laboratory diagnostic test in rabies. The development of the symptoms must be awaited to make the diagnosis in people bitten by rabid animals. The ordinary disinfecting dressings of bichloride of mercury and carbolic acid solutions are worthless for the bites of rabid animals. It is necessary to use the actual cautery or fuming nitric acid in order to certainly remove rabies virus from a wound.

Yellow Fever.—This is an acute infectious disease chiefly of tropical countries, characterized by great prostration, severe pains, hemorrhages, and jaundice. The cause is not known. The disease is transmitted by the mosquito called *Stegomyia calopus*, which takes some of the infective blood from a patient and transmits it to another person. The virus is in the patient's blood in a condition in which the mosquito can take it during only the first three days of fever. Some cycle of development of the virus takes place in the mosquito because the insect is only capable of depositing it in a bite when twelve days shall have elapsed since it bit a yellow-fever patient. More than that, five days elapses between the bite of the mosquito and the appearance of the virus in the patient's blood. Because of these facts the modern conception of yellow fever supposes a protozoön as the cause. There are no laboratory diagnostic measures nor as yet any specific treatment. The spread of yellow fever is prevented by destroying the breeding places of the mosquito, a difficult thing, since this insect breeds in lowlands and bushes and in houses. It bites usually in the late afternoon.

Typhus Fever.—Although this condition is not understood clearly, it now seems that body lice, flies, and ticks transmit it. It is a filterable virus also and can be transmitted to monkeys. A bacterium has lately been found, however, which in certain ways seems to have something to do with the disease. Typhus fever exists in America in a mild form known as Brill's disease.

Scarlet Fever.—This is variously ascribed to protozoa and to streptococci; neither claim is well supported. The virus is in the blood and can be transmitted to monkeys at the height of the attack; in these animals a fever occurs, but no disease typical of scarlatina. The virus may be also in the peeling skin.

Measles.—As in the former disease various microorganisms have been held responsible but no certain one can be convicted. The virus in the blood of patients, in their nasal and buccal secretions, and when any of these are transferred to a monkey a fever quite like that of the human disease will develop. The viruses of both diseases are filterable.

Poliomyelitis.—This is an acute apparently infectious disease characterized by a mild constitutional illness followed by gradually appearing and progressing paralyses. It may be sporadic or appear in epidemics. The infective agent and its mode of transmission are not known. It probably enters by the nose and throat. The virus is present in the blood, lymph glands, and especially in the central nervous system. It is so small that it will pass through porcelain filters such as are used for water purification. The disease may be reproduced in monkeys by injecting this virus

by almost any route, and it is strictly comparable to that seen in human beings. It is not known how the virus leaves the body, but as the nose and throat seem the most likely places, they should be disinfected in both frank and mild ambulant cases and in attendants by the use of hydrogen peroxide solution. There is as yet no reliable specific treatment. The only laboratory test consists in finding in the cerebrospinal fluid an excess of a certain organic substance called globulin and a very small number of cells.

Mumps.—This is an acute inflammatory infectious disease of the salivary glands, the cause of which is not known. It is disseminated by direct contact, and the virus is in the saliva.

Other Diseases.—Other diseases which human beings may contract due to invisible viruses, are foot-and-mouth disease of cattle, dengue, trachoma, beri-beri, and pellagra. Nearly all of these viruses are small enough to go through a porcelain filter. It may be said in general that to protect one's self from the infection the local lesions and skin eruptions should be disinfected.

Acute Articular Rheumatism.—The modern conception of this disease is that it is an acute infection. Many bacteria have been described as its cause, but their defenders have not built up unanswerable arguments in their support. The theory now holding the stage is that a streptococcus called *Streptococcus rheumaticus* enters by the tonsils, penetrates to the blood stream, and settles in the joints. Certain it is that we frequently have streptococcus sore throat associated with acute rheumatism, and that the

inflammations of the heart lining after this disease are frequently streptococcal.

Impetigo Contagiosa.—This is an acute pustular eruption of the skin, thought, but not proven, to be due to the pus cocci. Some observers maintain that a protozoön is the cause. At all events pus cocci, both streptococci and staphylococci, are present. The lesions are at first pustules, but soon break down to flat ulcers. They occur chiefly upon the face. The disease is transmitted by direct intimate contact, such as kissing. Mild antiseptics are sufficient: 1 to 1000 carbolic acid or 1 to 3000 corrosive sublimate. A salve of mercury is usually prescribed. Its importance is greatest in surgical and children's wards and clinics and in schools.

Noma or Cancrum Oris.—This is a perforating ulceration, usually of the cheek, on weak and debilitated children. It is said to be due to a host of different organisms, cocci, pseudodiphtheria bacilli, and many others. The one most frequently found is an anaërobic germ of double appearance, as a rod and as a spirochete. The treatment is of a radical surgical character, as ordinary external applications are unavailing. It is not very contagious, but discharges and sloughs are best burned.

GLOSSARY.

THE meaning of many words occurring several times in the text is given here that the reader may the more intelligently follow the subject matter. Certain unusual terms used seldom and sufficiently explained under special headings are not repeated here. Nearly all words in scientific language are derived from Latin or Greek roots and are to be pronounced precisely as printed.

Aërobic—Preferring or demanding atmospheric oxygen for life.

Agglutinins—Substances in the serum capable of clumping bacteria. Related words: to agglutinate, agglutination.

Anaërobic—Preferring or demanding the absence of atmospheric oxygen for life.

Anaphylaxis—A condition of high sensitivity due to idiosyncrasy to or previous injection with certain organic substances but otherwise unexplained as yet. Symptom: shortness of breath, skin irritations, and sometimes death.

Antibodies—Substances developed in the blood serum which neutralize the toxins of bacteria, but this word is usually used with reference to intracellular toxins.

Antitoxins—Antibodies developed in the blood serum which neutralize extracellular toxins of bacteria.

Asexual—Applied to forms that can multiply without being divided into two separate and recognizable sexual elements.

Attenuate—To reduce in virulence.

Bacillus (pl., **Bacilli**)—The genus of motile rods in the vegetable kingdom.

Bacteriaceæ—The family of rod-shaped bacteria.

Bactericide—A substance used to kill bacteria; also called a "germicide." Related word: bactericidal.

Bacterins—The dead bodies of bacteria used to treat disease by injection under the skin; also called "vaccines."

Bacteriology—The study of bacteria. Adj., bacteriological.

Bacteriolysin—An antibody that will dissolve bacteria. Related words: bacteriolysis, bacteriolytic.

Bacterium (pl., **Bacteria**)—From Greek word meaning little stick; the genus of non-motile rods. The words are also used to mean any of these lowest plants.

Carrier—A term applied to a person who carries germs capable of being transmitted to and infecting others, but himself not necessarily suffering at the time from the disease caused by the germ.

Cell—The smallest recognizable unit in biology. Cells are single and independent in bacteria and protozoa, but are combined and dependent upon one another in the higher plants and animals.

Coccaceæ—The family of the spherical vegetable organisms.

Coccus (pl., **Cocci**)—A spherical organism.

Colony—The individual group growing upon laboratory foodstuffs, and usually referring to one small group. The word is used for the growths upon flat dishes that are supposed to arise from a single organism.

Commensal—Living in harmless union either independently or for mutual benefit.

Complement—A constituent of all sera which helps in the union of antibodies and bacteria.

Cultivation—A word used to embrace all the procedures employed to make germs grow under the laboratory conditions.

Culture—The mass of bacteria grown artificially upon laboratory foodstuffs. The general term applied to the way bacteria grow. See Colony. Adj., cultural.

Cytoplasm—The soft part of a cell between the wall and the nucleus; also called protoplasm.

Dejecta—The feces and urine; also used to mean sputum, sweat, and morbid discharges.

Disinfection—The destruction of infective material. See p. 53 for various degrees.

Encystment—The grouping together within a resistant membrane of forms or stages in the life cycle of organisms, or a resting stage when conditions for life are unfavorable.

Enzyme—The products of life of organisms by which they digest their foodstuffs. A substance capable of splitting others into simpler ones without itself undergoing any change or entering into the new product. Also called ferment. Related words: enzymic, enzymatic.

Etiology—Study of the cause of a disease and its transmission; also the cause itself.

Ferment (pronounced fĕr-ment)—See Enzyme.

Fermentation—The breaking of sugars and starches (carbohydrates) by bacterial ferments, with the production of carbon dioxide, alcohols, and sometimes acids. Related words: to ferment, fermentative.

Genus—Next to the lowest division of biological classification, including members of the lowest division, species, among which there are only slight differences. Members of a genus must be alike in all important characters. See Species.

Germination—The progressive multiplication of the active adult forms.

Growth—A word used to cover the appearance of a culture on laboratory media, and sometimes used interchangeably with culture.

Host—The body which carries a parasite.

Immunity—The resistance of the body to illness. See p. 71 for kinds. Related words: to immunize, immunization, immune.

Infective—Any material carrying disease viruses.

Inhibit—Restrain, limit.

Inject—To put anything within the body; in this book it usually means to put beneath the skin.

Inoculate—To put some infective material within the body; usually used in experimental work upon lower animals.

Inorganic—Of the mineral world and not necessarily associated with living matter; example, salt. See Organic.

Isolate—Used to indicate the procuring of germs from morbid fluids or to the obtaining of a single kind, a pure culture, usually by finding one type of colony. Related word: isolation.

Lesion—Used to indicate any physical change from normal.

Leukocytes—The colorless, so-called white cells of the blood.

Medium (pl., **Media**)—General name given to foodstuffs upon which bacteria are grown artificially.

Micrococcus—The germs of spherical organisms dividing in two planes.

Morphology—A study of the physical nature, size, and shape of any object. Adj., morphological.

Nucleus (pl., **Nuclei**)—A mass within a cell clearly outlined from and denser than the cytoplasm or protoplasm, and in which the reproductive powers of the cell probably lie.

-ology—A suffix meaning a "study of" the root, such as morphology, which see.

Opsonins—Substances in the blood serum which prepare foreign bodies, usually bacteria, for consumption by the white cells of the blood, the phagocytes.

Optimum—The best, most suitable.

Organic—A substance having the form, the chemistry, or some characteristics of living matter; example, egg white. See Inorganic.

Parasite—An organism living on or in a host to the detriment of the latter. Adj., parasitic.

Pathogenic—Capable of producing disease.

Pathology—The study of disease—the broad subject of the cause, production, and result of disease, and especially the changes it produces in the body. Related words: pathologic, -al.

Phagocytosis—The act of consuming foreign bodies, notably bacteria, by the large white cells of the blood, called phagocytes. Adj., phagocytic.

Plane—The geometrical dimension. There is one plane in a line, two planes in a surface, and three planes in a body, such as a cube.

Plasma—The fluid part of the blood including the constituents capable of clotting. See Serum.

Poisons—Used generally to indicate any substance dangerous to body. Has no particular significance for bacterial products when used alone.

Proliferate—To multiply, increase.

Prophylaxis—Guarding against beforehand. Measures toward preventing disease. Adj., prophylactic.

Protoplasm—See Cytoplasm.

Protozoa (sing., **Protozoön**)—The lowest order of animals, independent single-celled organisms.

Pseudo—False, resembling.

Pseudopods—The foot-like projections of the cell wall and cytoplasm shown by amebæ, a method of progression for these protozoa.

Putrefaction—The decaying of proteid (the large part of meat and fish) with the production of foul odors and poisonous substances. (This is to be contrasted with fermentation, which see.)

Pyogenes—Pus-producing. Adj., pyogenic.

Saprophyte—An organism capable of living on dead or decaying matter. Adj., saprophytic.

Serum (pl., **Sera**)—The clear light yellow fluid part of the blood which exudes after clotting has occurred, and in which antibodies reside.

Sexual—Requiring two different forms for reproduction.

Species—The lowest biological division of living forms, varying only in unimportant characters, but possessing all the characters of the genus to which they belong. Lions and tigers belong to the genus Felis (or cat), but the former belongs to the species "leo," and the latter to the species "tigris." See Genus.

Spirocheta (pl., **Spirochetæ**)—The spiral or corkscrew-like organisms; name given both to family and genus.

Staphylococcus—The spherical coccus which grows in grape-like masses.

Sterile—Bacteriologically speaking, entirely free of living organisms. A surgically sterile thing may contain organisms from the air which do not hurt the patient. Related words: sterility, sterilization, to sterilize.

Strain—An individual culture of a species isolated from a case.

Streptococcus—The spherical coccus which grows in chains.

Toxins—The poisonous products of bacterial life.

Tumefaction—Any tumor-like swelling.

Vaccine—Originally used for the inoculation of cow-pox as a protective against smallpox; now used for that and for the injection of dead or attenuated bacteria for active immunization or treatment during disease. See Bacterins. Related words: to vaccinate, vaccination.

Viable—Capable of living and reproducing.

Virulence—The power possessed by organisms to develop poisons and produce disease. It varies in different strains, but depends also upon the resistance of the host.

Virus—Any factor which produces disease, either individually recognized or obscure; usually applied to poisons not specifically isolated, like rabies virus.

INDEX.

C

D

N

O

P

T

Y

THE PACIFIC COAST JOURNAL
OF NURSING

THE FA[illegible] JOURNAL
OF NURS[illegible]

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